CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 58 APRIL 1972 NUMBER 2

California Fish and Game is a journal devoted to the conservation of wildlife. If its contents are reproduced elsewhere, the authors and the California Department of Fish and Game would appreciate being acknowledged.

The free mailing list is limited by budgetary considerations to persons who can make professional use of the material and to libraries, scientific institutions, and conservation agencies. Individuals must state their affiliation and position when submitting their applications. Subscriptions must be renewed annually by returning the postcard enclosed with each October issue. Subscribers are asked to report changes in address without delay.

Please direct correspondence, except regarding paid subscriptions, to:

CAROL M. FERREL, Editor
California Fish and Game
987 Jedsmith Drive
Sacramento, California 95819

Individuals and organizations who do not qualify for the free mailing list may subscribe at a rate of $2 per year or obtain individual issues for $0.75 per copy by placing their orders with the Office of Procurement, Documents Section, P.O. Box 20191, Sacramento, California 95820. Money orders or checks should be made out to Office of Procurement, Documents Section. Inquiries regarding paid subscriptions should be directed to the Office of Procurement.

CALIFORNIA FISH AND GAME

VOLUME 58 APRIL 1972 NUMBER 2

Published Quarterly by
STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF FISH AND GAME

CONTENTS

	Page
Angling Quality at Folsom Lake, California, as Determined by a Roving Creel Census — *C. E. von Geldern, Jr.*	75
White Sturgeon Population Characteristics in the Sacramento-San Joaquin Estuary as Measured by Tagging — *Lee W. Miller*	94
Migrations of Sturgeon Tagged in the Sacramento-San Joaquin Estuary — *Lee W. Miller*	102
Molting and Growth in Laboratory Reared Phyllosomes of the California Spiny Lobster, *Panulirus interruptus* — *Deborah M. Dexter*	107
Southern California Pacific Mackerel Fishery and Age Composition of Commercial Landings During the 1968–69 and 1969–70 Seasons — *Eric H. Knaggs*	116
Age and Length Composition of Northern Anchovies, *Engraulis mordax*, in the California Anchovy Reduction Fishery for the 1969–70 Season — *Jerome D. Spratt*	121
Acute Toxicity of Four Organochlorine Insecticides to Two Species of Surfperch — *Russell D. Earnest* and *Pete E. Benville, Jr.*	127
The Mineral King Deer Herd — *Edward R. Schneegas* and *George W. Franklin*	133
Rabies in Deer — *D. T. Cappucci, Jr.* and *W. M. Longhurst*	141
Notes	
Nonreporting of Tagged Largemouth Bass — *Robert R. Rawstron*	145
Tailless Dover Sole from Off the Oregon Coast — *Robert L. Demory*	147
A Polypropylene Light Trap for Aquatic Invertebrates — *Lawrence R. Epinosa* and *William E. Clark*	149
Tolerance of High Salinity by the Pileworm, *Neanthes succinea*, from the Salton Sea, California — *Jack A. Hanson*	152
Range Extension of *Palaemonetes paludosus* (*Gibbes*) in California — *James A. St. Amant* and *John S. Day*	156
Book Reviews	

Calif. Fish and Game 58(2): 75–93. 1972.

ANGLING QUALITY AT FOLSOM LAKE, CALIFORNIA, AS DETERMINED BY A ROVING CREEL CENSUS[1]

C. E. VON GELDERN, JR.
Inland Fisheries Branch
California Department of Fish and Game

A creel census was conducted at Folsom Lake, California, on 96 days from January through December 1962, to obtain a measure of angling quality on this large west slope Sierran impoundment. Census clerks interviewed 11,022 anglers who fished 24,957 hr and caught 8,131 game fish. Bluegill (*Lepomis macrochirus*), smallmouth bass (*Micropterus dolomieu*), and largemouth bass (*M. salmoides*), dominated the catch. Fishing pressure was highest in spring and lowest in winter. Angler success was highest in summer and early fall. Estimated total use and catch during 1962 were 299,155 angler hours and 88,918 game fish. Evidence is presented which suggests that the black basses may be overexploited in relation to competing centrarchids. Other segments of the fishery, however, appear capable of supporting greater angler pressure. The value of detailed data on angling methodology as a means of more accurately describing the various segments of a complex multi-species fishery is conclusively demonstrated.

INTRODUCTION

California's development in the last several decades has featured the construction of a great many large impoundments in the foothills of the Central Valley and Coast Range. These waters characteristically support an assemblage of warmwater game fish species dominated by centrarchids and ictalurids. Impoundments with well oxygenated hypolimnions also sustain salmonid populations. The mediocre quality of angling generally available in these waters has long been recognized (Abell and Fisher 1953, Kimsey 1958) and efforts to solve the fishery management problems associated with them have greatly increased in recent years. This activity has accentuated the need for increased knowledge on present fishing quality against which the effectiveness of new management programs can be measured. Creel checks are among the best available tools for this purpose since they provide direct measures of the fishermen's catch and can be designed to produce information on total use and yield, harvest of planted fish, fishery exploitation rates, fish migratory patterns, and fish habitat preferences.

Folsom Lake, a 10,450-acre fluctuating reservoir with multiple access points, was selected for intensive study in 1962 because it is typical of many impoundments on the east side of the Central Valley. The reservoir is well described by Tharratt (1966), and it need only be mentioned here that this impoundment is located about 20 miles east of Sacramento and was formed by the completion of Folsom Dam in 1955. Research activity on the reservoir was broad in scope and provided information on limnology (Rawstron 1964), fish distribution (von

[1] Accepted for publication September 1971. This work was performed as part of Dingell-Johnson Project California F-18-R, "Experimental Reservoir Management", supported by Federal Aid to Fish Restoration funds.

2—82862

Geldern 1964), centrarchid age and growth (Tharratt 1966), fish harvest, mortality, and movement (Rawstron 1967), and angling quality. This report describes the creel census phase of the Folsom Lake research effort and places special emphasis on the consideration of angling methods as a means of more accurately describing the various segments of a multi-species fishery.

METHODS

Roving type census procedures were used at Folsom Lake because it is generally recognized that angler contacts on large bodies of water with multiple access points are most efficiently made by census clerks transversing the area by boat (Grosslein 1962). Waiting time between interviews is limited to travel time between anglers. Roving type censuses permit contact with all types of fishermen (rental boat, private boat, shore) in proportion to their actual abundance. This would be difficult to achieve by census clerks stationed at landings, particularly if significant numbers of anglers fished from private docks. It is also virtually impossible for census clerks at landings to cover the shore fishery evenly on large waters. These deficiencies could easily create serious errors in catch rate estimates if the various angler groups harvested fish at different rates. A final advantage of the roving type census is that it can also be combined with angler use counts to provide data on trends in fishing pressure (Jessen 1956).

During periods of high use, two census clerks in separate boats toured the lake in a counterclockwise direction and contacted all boat and shore anglers seen. The lake was divided into two approximately equal parts and each census clerk worked only in his assigned section so that overlap did not occur. A second complete check of anglers was often possible on days when fishing pressure was light. Occasionally the second check included only a fraction of the anglers present. One census clerk often checked the entire lake on days when light fishing pressure was anticipated. Daily censuses varied in duration depending on the number of daylight hours and density of fishing pressure. The minimal period covered was 9 AM to 5 PM, but the census often included a broader time span during the spring and summer months. Creel checks were conducted on 53 weekdays and 43 Saturdays or holidays during 1962. Census effort per month ranged from a low of 3 days in February to a high of 12 days in May (Table 1).

The following information was obtained from each party of anglers contacted: (i) boat or shore anglers; (ii) number of anglers in party; (iii) total hours fished by all members of party; (iv) angling method; and (v) fish taken by numbers and species. Periodically, lengths of fish caught were recorded to the nearest inch.

For purposes of data analysis, the angling effort was divided into the following categories: (i) trolling; (ii) lures; (iii) minnows; (iv) worms; (v) minnows and lures; (vi) minnows and worms; (vii) lures and worms; (viii) sardines; (ix) sardines and worms; (x) lures, minnows, and worms; and (xi) all others. Parties of anglers who did not restrict their entire pre-interview fishing time to one of the above specific angling categories were placed in the "all others" group.

TABLE 1. **Pattern of Census Effort at Folsom Lake, 1962.**

Month	Days censused		
	Weekdays	Saturdays or holidays	Total
January	0	4	4
February	0	3	3
March	0	5	5
April	6	4	10
May	9	3	12
June	5	3	8
July	7	4	11
August	6	3	9
September	4	5	9
October	4	3	7
November	8	2	10
December	4	4	8
Totals	**53**	**43**	**96**

Field data were coded and transferred to IBM cards for processing on a UNIVAC 1107 using FORTRAN IV. Except for January, February, and March when weekday censuses were not conducted because of low use, the computer program provided monthly summaries of catch statistics collected from four basic groups of anglers: Saturday and holiday boat fishermen; weekday boat fishermen; Saturday and holiday shore fishermen; and weekday shore fishermen. Within each of these basic groups, the number of fishermen using the various angling techniques, their recorded effort, and catch rates (ratio of the means estimator) by species were given.

A major disadvantage of the roving census is that only limited angler effort expended late in the day is normally recorded. This could create serious errors in catch rate estimates if fishing quality at dusk changed significantly. In an attempt to ascertain the magnitude of this problem, completed effort checks which featured clerks stationed at landings were conducted on 5 days in the spring when roving checks were also made. A comparison of the catch rates recorded by the two methods revealed that roving checks produced somewhat higher catch rates for predator species (largemouth and smallmouth bass) and slightly lower catch rates for the lesser sunfishes. This phenomenon was related to anglers changing fishing techniques rather than changes in fishing quality. A high percentage of Folsom Lake anglers fished for bass first and later changed methods and tried for sunfish or catfish. The roving check, therefore, produced data containing a higher percentage of efficient bass fishing effort than the completed check.

A comparison of the catch rates of anglers using a single method and returning to landings before and after 5 PM was also made. Success rates for the two groups were virtually identical on all days. These findings strongly suggest that available angling quality did not change dramatically during the day and support the decision to use the roving census method at Folsom Lake.

CENSUS RESULTS

General Fishery Characteristics

Census clerks interviewed 4,597 boat and 6,425 shore anglers who fished 12,073 and 12,884 hr, respectively. The catch totaled 8,131 game fish and was dominated by bluegill, smallmouth bass, and largemouth bass. Other species taken were green sunfish (*Lepomis cyanellus*), red-ear sunfish (*L. microlophus*), white catfish (*Ictalurus catus*), brown bullhead (*I. nebulosus*), black bullhead (*I. melas*), channel catfish (*I. punctatus*), and rainbow trout (*Salmo gairdneri*).

Hourly catch rates of boat and shore anglers were 0.31 and 0.34. Shore anglers generally had higher catch rates for sunfish and catfish, while boat anglers were more successful for black bass and rainbow trout (Table 2).

TABLE 2. Catch Composition and Catch Rates of Boat and Shore Anglers at Folsom Lake, 1962.

	Boat anglers			Shore anglers		
Species	Number fish seen	Catch/ hour	Percentage of total	Number fish seen	Catch/ hour	Percentage of total
Largemouth bass	730	0.06	19.4	516	0.04	11.8
Smallmouth bass	965	0.08	25.6	612	0.05	14.0
Bluegill	1,399	0.12	37.1	2,130	0.17	48.8
Green sunfish	78	0.01	2.1	265	0.02	6.1
Red-ear sunfish	29	+	0.8	193	0.01	4.4
White catfish	288	0.02	7.6	344	0.03	7.9
Brown bullhead	31	+	0.8	114	0.01	2.6
Black bullhead	12	+	0.3	73	0.01	1.7
Channel catfish	10	+	0.3	34	+	0.8
Rainbow trout	224	0.02	5.9	84	0.01	1.9
Totals	**3,766**	**0.31**	**99.9**	**4,365**	**0.34**	**100.0**

Recorded catch rates of weekday and Saturday or holiday anglers were very similar. From April through December (when both weekday and Saturday or holiday checks were made each month) the catch rates of boat anglers who fished on Saturdays and/or holidays and weekdays were 0.34 and 0.35 fish per angler hour. The catch per angler hour of shore fishermen who fished on Saturdays and/or holidays and weekdays was 0.37 and 0.40. The catch composition of the two categories of boat and shore angler was also similar (Table 3).

During 1962, census clerks measured 1,421 fish to the nearest inch (fork length). Mean lengths of fish measured by species were: largemouth bass, 11.7; smallmouth bass, 11.3; bluegill, 5.6; red-ear sunfish, 7.2; green sunfish, 5.1; white catfish, 11.4; brown bullhead, 11.7; black bullhead, 11.5; channel catfish, 12.7; and rainbow trout, 14.1.

Seasonal Trends in Angler Use and Catch

The average number of anglers contacted per census day in a single complete tour of the lake by month was used as a criterion for determining seasonal trends in angler effort. Generally, angler use was low in winter, high in spring, and intermediate in the summer and fall.

TABLE 3. Percentage Composition of Catch of Weekday and Saturday and or Holiday Anglers at Folsom Lake from April Through December, 1962.

Species	Percentage composition of catch			
	Boat anglers		Shore anglers	
	Weekdays	Saturdays or holidays	Weekdays	Saturdays or holidays
Largemouth bass	17.2	17.1	10.0	12.2
Smallmouth bass	24.8	25.4	13.1	13.1
Bluegill	38.7	40.3	49.1	53.6
Green sunfish	1.8	2.4	5.8	7.0
Red-ear sunfish	1.2	0.6	7.3	2.0
White catfish	6.5	8.5	8.3	7.4
Brown bullhead	0.6	0.5	1.7	1.3
Black bullhead	0.4	0.3	2.2	1.1
Channel catfish	0.5	0.1	0.7	0.9
Rainbow trout	8.1	4.7	1.7	1.3
Totals	**99.8**	**99.9**	**99.9**	**99.9**

Saturday and holiday boat angler effort rose steadily from a low of 33.8 anglers contacted per census day in January to a high of 160.3 anglers in June. This was followed by a steady drop to 45.2 anglers per day in September. A second minor increase in effort occurred in October and November followed by low use in December (Figure 1). Weekday boat angler effort was highest in April (the first month that weekdays were censused), dropped significantly in May, remained fairly constant from June through October, and dropped to relatively low levels in November and December. The density of Saturday and

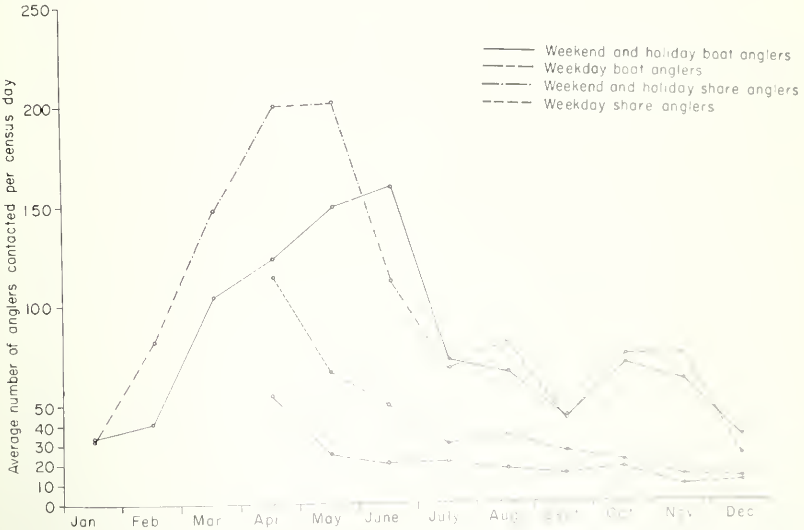

FIGURE 1. Seasonal trends in fishing pressure at Folsom Lake, 1962, as determined by the average number of anglers contacted per census day. Weekday creel checks were not conducted in January, February, and March.

holiday boat anglers averaged about four times greater than weekday boat anglers during the April through December period.

Saturday and holiday shore angler use followed a pattern similar to Saturday and holiday boat anglers. Maximum effort occurred in April and May when averages of 201.8 and 203.7 anglers were contacted per census day. Weekday shore angler use was highest in April when an average of 115.0 anglers were contacted per census day. Fishing effort declined thereafter except for a slight increase in August (Figure 1).

The average number of anglers contacted per census day from April through December (weighted by month) was as follows: weekend and holiday shore anglers, 98.8; weekend and holiday boat anglers, 87.6; weekday shore anglers, 41.4; and weekday boat anglers, 21.8.

Data on seasonal trends in angler success combined Saturday, holiday, and weekday anglers within boat and shore categories since their catch rates and catch compositions were similar. Monthly catch rates are expressed simply as the total number of fish censused during the month (by species or combination of species) divided by total hours fished.

Boat angler catch rates for all game fish species combined were low in the late winter and early spring, increased to maximum levels in the summer, and declined to intermediate values in the fall and early winter. Monthly catch rates ranged from a low of 0.09 fish per hour in January to a high of 0.53 fish per hour in August (Figure 2).

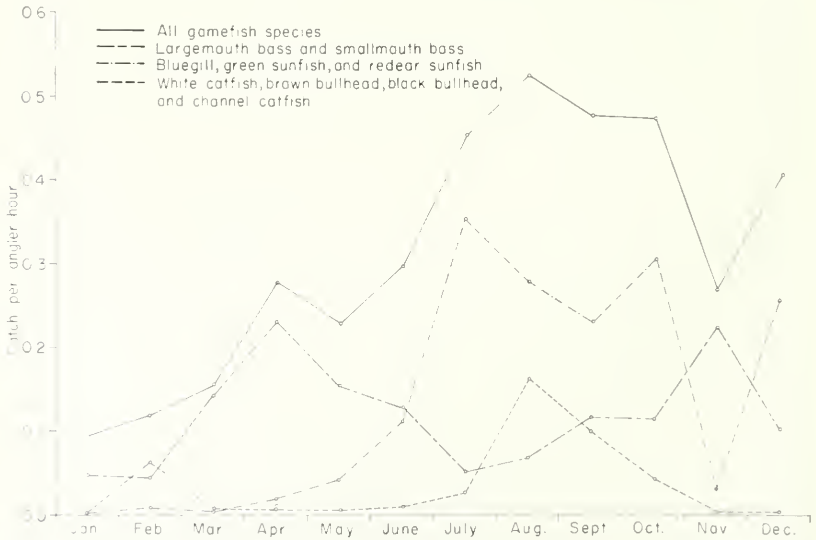

FIGURE 2. Seasonal trends in catch per angler hour for boat anglers at Folsom Lake, 1962.

Largemouth and smallmouth bass dominated the boat fishery during March, April, and May when catch rates of 0.14, 0.23, and 0.16 were recorded. These species declined in importance during the summer and early fall, but again dominated the fishery in November with a catch rate of 0.22 fish per hour.

The boat angler catch rate for sunfish was low from January through May. Angler success began to improve in June and reached a peak of 0.36 fish per hour in July (Figure 2). Catch rates remained relatively high through October, declined in November, and increased to summer levels in December.

Catfish angling (boat fishermen) was characterized by two peaks in angler success: a minor one in February when the catch rate was 0.06 fish per hour and a second in August and September when catch rates of 0.16 and 0.10 were recorded. Angler success in the remaining months was below 0.05 fish per hour. The February peak was dominated by brown bullhead and the August and September peak by white catfish.

Seasonal trends in catch rates of shore anglers were roughly similar to those of boat anglers (Figure 3). Largemouth and smallmouth bass had comparable spring and fall peaks in angler success. Sunfish were dominant in summer, and catfish angler success was again characterized by peaks in angling quality in February and in September and October. Generally, shore anglers had higher catch rates for sunfish and catfish, while boat angler success was greater for largemouth and smallmouth bass.

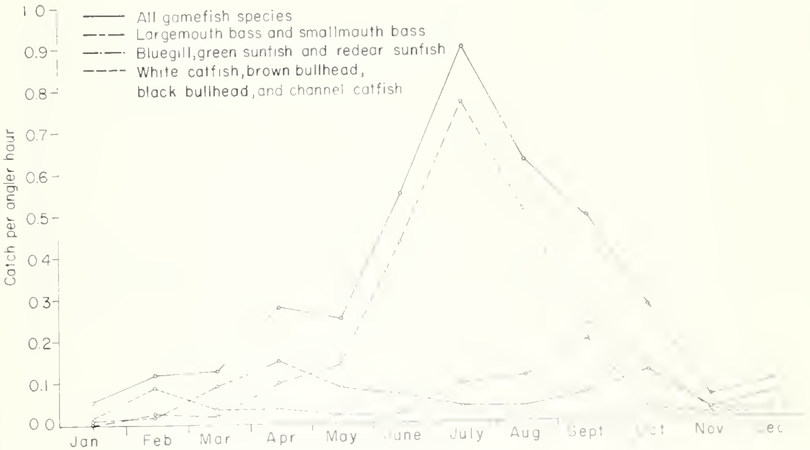

FIGURE 3. Seasonal trends in catch per angler hour for shore anglers at Folsom Lake, 1962.

Angler success for rainbow trout (not shown in Figures 2 and 3) was uniformly low throughout the year. This species made its most significant contribution to the catch in April, May, and June.

INDICES OF FISHING QUALITY

The quality of angling available for a given species (or group of species) is best measured by those anglers who use relatively efficient angling methods. The computer output from the Folsom Lake census summarized catch rates and catch compositions for 11 commonly encountered angling techniques with breakdowns within each category (when applicable) for boat and shore anglers (Appendix I). These summaries provide the basis for the selection of those categories of

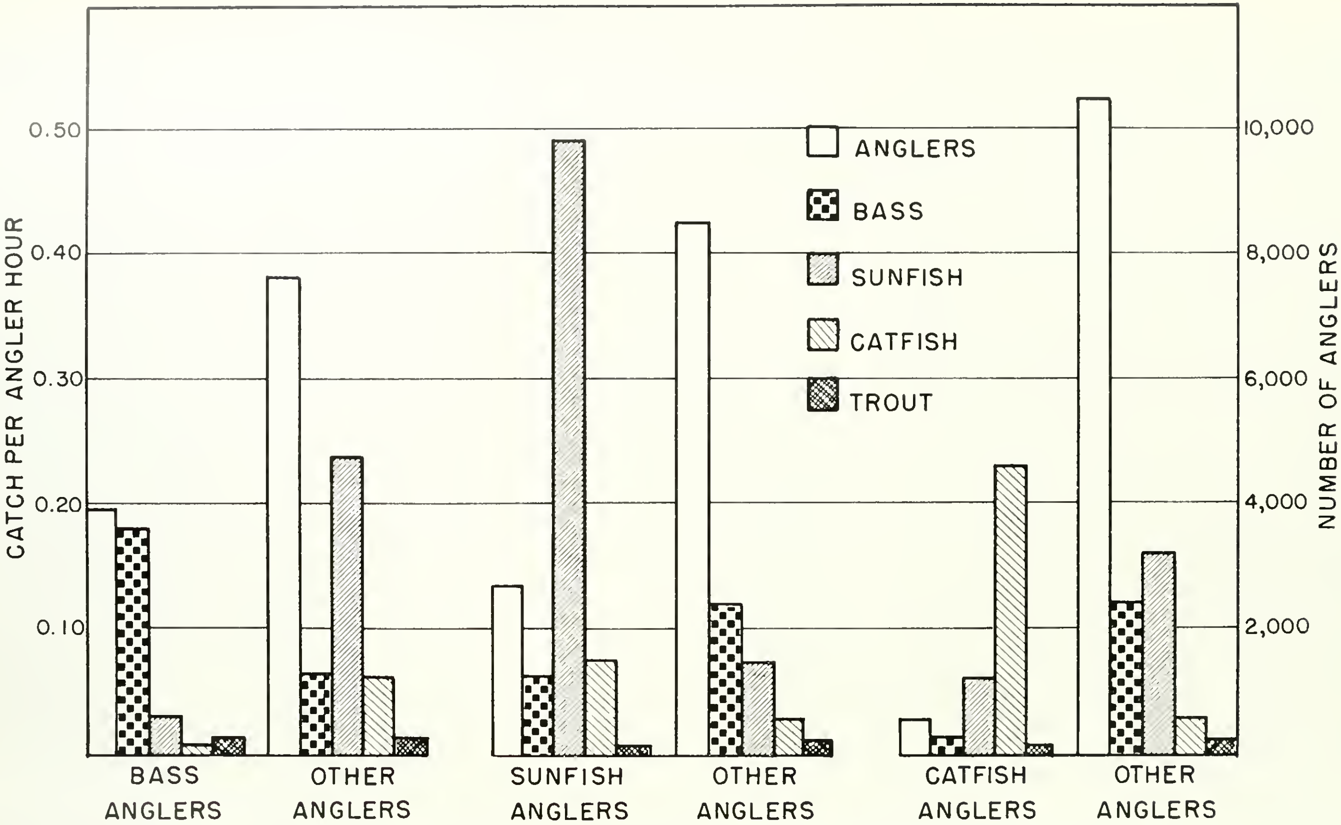

FIGURE 4. A comparison of the catch rates and catch compositions of anglers using efficient methods for bass, sunfish, and catfish, with the remaining groups of anglers at Folsom Lake, 1962.

anglers which best describe the various segments of the Folsom Lake fishery.

Criteria used for selecting angler categories to describe fishery trends of individual species or groups of closely allied species are as follows: relatively high catch per angler hour; relatively high percentage composition of species in catch; and popularity of angling method. Of necessity, the selection of angler categories involved certain arbitrary judgments, since I was unable to develop a selection formula equally applicable to all species.

For purposes of describing angling quality at Folsom Lake, fishery data on closely related species were combined. For example, catch data and related statistics on largemouth bass and smallmouth bass were combined and treated simply as material descriptive of the bass fishery. Data on the three sunfish species and the four catfish species present were combined in a similar manner.

The Bass Fishery

Data collected from boat and shore anglers using lures, minnows, or minnows and lures in combination were selected to describe the bass fishery. Anglers using these efficient methods had a yearly bass catch rate of 0.18 per hour and a catch composition of 80% bass. Comparable values for the remaining groups of anglers were only 0.06 and 16% (Figure 4). The recorded effort of bass anglers was 9,382 hr (38% of the total) and their catch totaled 1,735 bass; 62% of all bass seen.

Seasonal trends in fishing quality for bass showed two major peaks in angler success. One of these occurred in April when a catch rate of 0.25 bass per hour was recorded. A second pronounced peak occurred in October when the catch rate reached a maximum of 0.22 bass per hour. Angler use was comparatively heavy during the spring period of relatively good angling. The fall peak in success was accompanied by only a slight rise in fishing pressure (Figure 5).

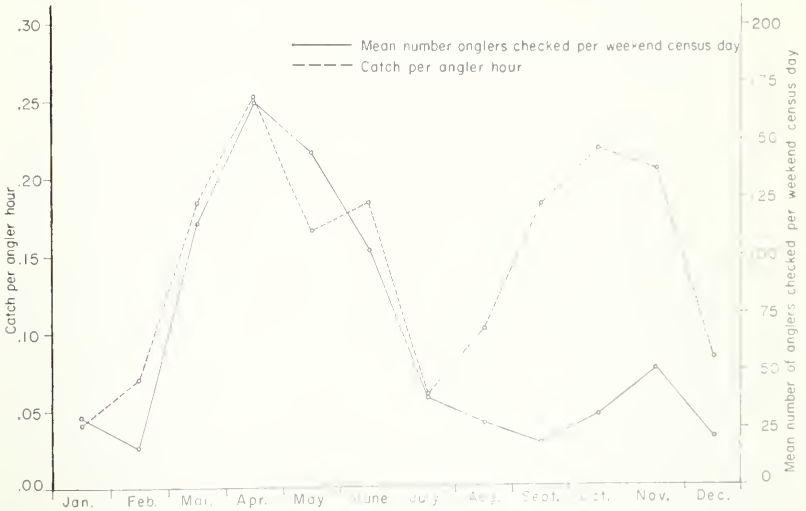

FIGURE 5. Seasonal trends in catch rate and effort for largemouth and smallmouth bass at Folsom Lake, 1962, by anglers using relatively efficient angling methods.

The Sunfish Fishery

Boat and shore anglers using worms best depicted the quality of the sunfish fishery (Appendix I). These anglers had a sunfish catch rate of 0.49 per hour as compared to 0.07 for the remaining groups (Figure 4). Their catch totaled 78% sunfish which represented 64% of all sunfish seen.

Sunfish angler success rose steadily during the spring and early summer, reaching a high of 1.17 fish per hour in July. A steady decline through November then occurred followed by a partial recovery in December. Angler use peaked in May and June and, except for an increase in October, steadily declined thereafter (Figure 6).

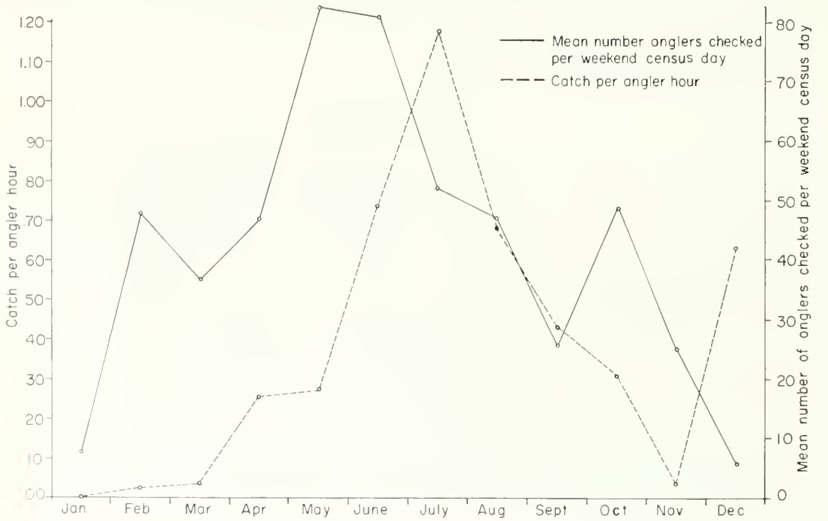

FIGURE 6. Seasonal trends in catch rate and effort for bluegill, green sunfish, and red-ear sunfish at Folsom Lake, 1962, by anglers using relatively efficient angling methods.

The Catfish Fishery

The selection of suitable angler categories to depict trends in fishing quality for catfish created special problems because only a few very small groups of anglers had relatively high catfish success rates. The most efficient angler categories were sardine anglers (boat and shore) and boat anglers using sardines and worms in combination (Appendix I). These groups had catch rates ranging from 0.22 to 0.57 catfish per hour. Catfish comprised 84.9 to 94.9% of the catch of these angler categories. Their total recorded effort, however, was only 658 hr. For this reason, shore anglers using sardines and worms in combination are included among those groups of anglers depicting the catfish fishery even though they were less efficient than the other angler categories. This latter angler category fished 592 hr, had a catch rate of 0.13 catfish per hour, and a catch composition of 49.4% catfish. The combined four groups of anglers fished 1,250 hr (5.0% of the total recorded effort) and caught 286 catfish (31.6% of all catfish seen) for a yearly catch rate of 0.23 catfish per angler hour (Figure 4).

Catfish angler success showed a minor peak in April when a catch per hour of 0.17 was recorded and a major peak in August and September when catch rates reached 0.36 and 0.47, respectively. Angler use fluctuated considerably reaching a peak in August when an average of 20.3 anglers per weekend census day were contacted (Figure 7).

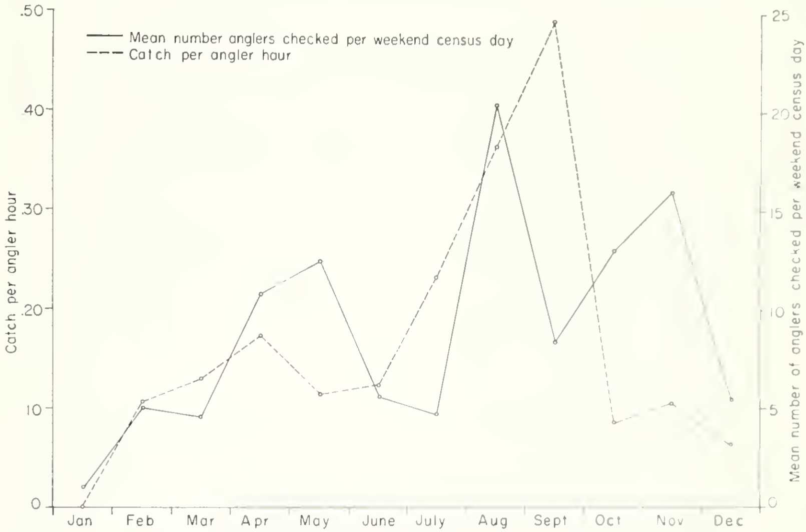

FIGURE 7. Seasonal trends in catch rate and effort for white catfish, brown bullhead, black bullhead, and channel catfish at Folsom Lake, 1962, by anglers using relatively efficient angling methods.

The Rainbow Trout Fishery

Unfortunately, no single angler category or group of categories properly depict angling quality for rainbow trout. Trollers were most successful with a catch rate of 0.06 rainbow trout per hour as opposed to a catch rate of 0.01 for all anglers. Bass dominated the troll catch, however, and it appears probable that a significant percentage of trollers were fishing specifically for centrarchids (Appendix I). Catch rates for trout were low throughout the year, and their contribution to the catch was minor.

DISCUSSION

Census Methodology

While the census procedures employed at Folsom Lake produced generally satisfactory results, there were ways in which the quality of the data obtained could have been improved. Trollers should have been asked whether they were fishing for trout or bass. The addition of this feature to the census would probably have produced a body of data descriptive of the trout fishery as well as enhancing the material depicting angling quality for bass.

The techniques employed for measuring fish could also have been improved. Census clerks sometimes displayed a tendency to measure relatively large fish only when a portion of a catch was measured or

they were allowed to exercise their own discretion as to which catches to measure. The rule should be: measure all fish in a catch or none and never let the nature of the catch influence the decision to measure. Some sort of systematic procedure for measuring fish would clearly have enhanced the quality of the 1962 Folsom Lake census.

A more even and uniform within-day distribution of census effort would have been achieved if the lake was divided into areas and censused in accordance with a time schedule. For example, the lake could have been separated into four sections with section 1 censused from 9 AM to 11 AM, section 2 from 11 AM to 1 PM, etc. A schedule of this type would eliminate partial second checks and reduce the possibility of finishing the census early on days when fishing pressure is light. These objectives are obviously desirable since they help make between-day census data more comparable.

The categories of anglers used to depict the various segments of a multi-species fishery will differ considerably between waters. Local angling regulations, the availability of certain baits, and the species composition of the reservoir being censused are factors which need to be considered. At Pine Flat Lake, Fresno County, where black crappie (*Pomoxis nigromaculatus*), and white crappie (*P. annularis*) are present, anglers using minnows were most descriptive of the crappie fishery. The crappie fishery at Lake Nacimiento, San Luis Obispo County, however, was best described by anglers using crappie lures. In the latter case, fishing with minnows was not permitted and it was necessary to segregate anglers using crappie and bass lures in order to obtain material descriptive of both fisheries. Sardines were not readily available as bait at either Pine Flat Lake or Lake Nacimiento and the use of other groups of anglers to describe the catfish fishery was required. Because of these variations between waters, it will always be necessary to plan new censuses carefully and to record angler methodology in considerable detail. Creel checks conducted at Pine Flat Lake and Lake Nacimiento were also supported by D-J F-18-R and the formal results will be reported in separate publications.

Catch rate similarities of Saturday, holiday, and weekday anglers at Folsom Lake may be due, in part, to the reservoir's proximity to metropolitan areas. Presumably, weekday and weekend effort draws from the same pool of anglers. Impoundments in more remote locations, however, may be fished by relatively expert local anglers during the week and inexperienced tourists on weekends. The possibility that these two groups of anglers harvest fish at different rates should be considered when a census is being planned. In cases where an estimate of total use and catch is required it will probably be necessary to census on weekends and weekdays. Where simple indices of fishing quality are desired, weekend censuses only should be sufficient.

Fishery Trends Since 1962

Occasional creel checks conducted at Folsom Lake during March, April, and May of 1965, 1966, 1968, and 1969 provide some data on trends in fishing quality since 1962. The spring catch per angler hour

for all species combined in 1965 and 1966 was 0.31 and 0.34 as compared to a catch rate of 0.24 in 1962. In 1968 and 1969, comparable values were only 0.11 and 0.10 (Table 4).

Catch rates for bass declined from a high of 0.14 fish per hour in 1962 to a low of 0.02 in 1968. Sunfish catch rates were highest in the spring of 1965 when a value of 0.18 sunfish per hour was recorded. A precipitous decline has subsequently occurred which reached a low of 0.01 in 1968. Catfish catch rates have also declined in recent years. The salmonid catch, particularly kokanee (*Oncorhynchus nerka*), has increased since 1962 and is largely the result of stocking efforts.

The spring catch rate data are not strictly comparable between years for several reasons. Beginning in 1966, a relatively high percentage of anglers probably fished exclusively for salmonids which could easily depress recorded success rates for other species. Variations in spring weather conditions between years could also produce variations in catch rates not related to population abundance. The data, however, illustrate the importance of salmonid stocking to the spring fishery and also suggest that the warmwater fishery may have deteriorated.

Total Use and Catch

The creel census at Folsom Lake, while not designed to estimate total use and catch, provided the basis for making crude estimates of these parameters when combined with fishery statistics from other waters. During 1969, a similar roving type creel census was conducted at Clear Lake, Lake County. This census featured aerial use counts to make estimates of total use on 32 days when roving type censuses were conducted. Examination of these data revealed that an average of about 20% of the total estimated hours fished on each use count day was recorded by census clerks conducting the roving type census. Using this value, estimates of total daily use were made on each day the census was conducted at Folsom Lake. Monthly estimates of total use (expressed in angler hours) were then made for each major angler category by expanding these data in a way to account for days when creel checks were not made. Catch estimates were made by multiplying recorded catch rates by total use values.

Based on these criteria, anglers fished an estimated 299,155 hr to catch 88,918 fish at Folsom Lake in 1962 (Table 5). Assigning a mean weight of 0.2 lb. for sunfish and 1.0 lb. for all other game fish species, the harvest totaled 54,966 lb. Estimated effort and yield per acre were 26.1 hr and 4.8 lb., respectively.

These estimates obviously must be viewed with considerable reservation. Their accuracy must necessarily be based on the assumptions that incompleted and completed effort catch rates were comparable and that the distribution of within-day angler use at Clear Lake and Folsom Lake was similar. As noted in a previous section, completed effort checks conducted in the spring on the same days that roving checks were also made consistently produced somewhat lower catch rates for bass (10–20%) and slightly higher catch rates for sunfish. While these differences are likely to be at their peak in the spring (when good bass fishing is available and the number of daylight hours is long) the estimate of the total bass catch may be biased on the high side.

TABLE 4. **Some Comparisons of Census Results at Folsom Lake During the Period March Through May in 1962, and 1965 Through 1969.***

Year	Catch per angler hour					
	Bass	Sunfish	Catfish	Trout	Kokanee	All species
1962	0.14	0.06	0.02	0.01	0.00	0.21
1965	0.10	0.18	0.02	Tr.	Tr.	0.31
1966	0.06	0.08	0.02	0.02	0.17	0.34
1968	0.02	0.01	Tr.	0.01	0.07	0.11
1969	0.01	0.03	Tr.	0.02	Tr.	0.10

* Tr. = less than 0.005.

TABLE 5. **Estimated Total Use and Catch at Folsom Lake, 1962.**

Angler category	Hours fished	Catch										
		Large-mouth bass	Small-mouth bass	Bluegill	Green sunfish	Red-ear sunfish	White catfish	Brown bullhead	Black bullhead	Channel catfish	Rainbow trout	Total
Boat anglers fishing weekends or holidays	111,961	6,418	8,543	13,427	863	275	2,769	291	101	56	1,586	31,362
Shore anglers fishing weekends or holidays	102,692	3,864	3,814	14,292	2,203	513	2,311	988	342	232	555	29,114
Boat anglers fishing weekdays	64,195	3,644	4,873	6,611	352	232	1,221	270	95	108	1,591	19,003
Shore anglers fishing weekdays	20,307	643	956	2,977	398	256	610	253	172	52	122	6,439
Totals	**299,155**	**14,599**	**18,186**	**37,310**	**3,816**	**1,276**	**6,911**	**1,802**	**713**	**448**	**3,857**	**88,918**

A Comparison of the 1962 Folsom Lake Fishery with the Fisheries of Similar California Impoundments

Creel checks conducted at Millerton Lake, Fresno and Madera counties (Abell and Fisher 1953), and Pine Flat Lake, Fresno County (Strohschein 1959), provide a basis for qualitatively comparing the 1962 Folsom Lake fishery with the fisheries of similar impoundments on the east side of California's Central Valley. Estimated angler use and catch statistics from Folsom Lake in 1962 were: hours fished per surface acre, 26.1; game fish yield in pounds per surface acre, 4.8; game fish caught per angler hour, 0.30; and pounds of game fish caught per angler hour 0.18. The average of five yearly estimates of similar parameters (not weighted by reservoir size, fishing pressure, or other factors) obtained at Pine Flat and Millerton lakes were: hours fished per surface acre, 32.3; game fish yield in pounds per surface acre, 5.0; game fish caught per angler hour, 0.54; and pounds of game fish caught per angler hour, 0.15 (Table 6). These data indicate that, with the exception of a relatively low catch per angler hour, the 1962 Folsom Lake fishery was roughly comparable to the fisheries of Millerton and Pine Flat lakes in terms of use and yield.

The recorded fish yields from these bodies of water are considerably less than the national average of 22.6 lb. per surface acre (Jenkins 1968) and only a fraction of the estimated yields from California impoundments south of the Tehachapi Mountains (Bell 1952; McCammon 1953; Beland 1960; La Faunce et al. 1964).

Management Considerations

The 1962 census at Folsom Lake has attained certain data which have management implications for large warmwater reservoir fisheries. It is of particular interest that the great fluctuations in angler densities between Saturdays, holidays, and weekdays were not accompanied by changes in angler success or catch composition. This finding suggests that "competition of gear" and the interference of water skiers and other water associated recreationists (also more abundant on Saturdays and holidays than on weekdays) were not factors which significantly depressed angler success at Folsom Lake in 1962. Similarly, boat and shore anglers using the same angling methods and fishing for littorally oriented centrarchids also caught fish at comparable rates. This suggests that centrarchid population densities in areas easily reached by shore anglers were comparable to densities in more remote areas which could be reached only by boat. Since these species do not migrate extensively in large impoundments (Fisher 1953; Rawstron 1967), the conclusion follows that short-term exploitation rates are not excessive. Fisher (1953) came to essentially the same conclusion at Millerton Lake in 1950.

Boat anglers using sardines or sardines and worms in combination were considerably more successful taking catfish than their counterparts who fished from shore. White catfish, the dominant ictalurid in Folsom Lake, were most abuandant at depths from 30 to 50 ft during the summer (von Geldern 1964) which suggests that shore anglers may have been unable to reach dense white catfish populations.

Catfish generally have the reputation of being difficult to catch in large deep California impoundments, and tagging studies indicate that

TABLE 6. **A Comparison of the 1962 Folsom Lake Fishery with the Fisheries of Millerton and Pine Flat Lakes.**

Reservoir	Year	Fishing pressure		Catch characteristics					
		Total hours	Hours /acre	Number game fish caught	Pounds of game fish caught	Yield in lb./acre	Game fish caught/ angler hr	Pounds caught/ angler hr	Catch composition and miscellaneous remarks
Folsom[1]	1962	299,155	26.1	88,918	51,996	4.8	0.30	0.18	Bass, 37%; sunfish, 48%; catfish, 11%; trout, 4%; crappie absent.
Millerton[2]	1949	112,438	25.1	35,574	11,664	2.6	0.32	0.10	Bass, 22%; sunfish, 78%. A few trout taken. Black crappie present but do not contribute to fishery.
Millerton	1950	161,915	37.2	116,520	29,701	6.7	0.71	0.18	Bass, 11%; sunfish, 89%. A few trout caught.
Millerton	1951	208,932	46.0	132,386	34,050	7.5	0.63	0.16	Bass, 19%; sunfish, 81%.
Millerton	1952	168,820	37.6	69,700	22,879	5.1	0.41	0.14	Bass, 30%; sunfish, 70%.
Pine Flat[3]	1957[4]	90,770	15.1	57,031	19,051	3.2	0.63	0.21	Smallmouth bass, 12%; green sunfish, 68%; black crappie, 13%; catfish, 5%; trout, 2%. Largemouth bass and bluegill absent or nearly so.

[1] Present study.
[2] Millerton Lake data taken from Abell and Fisher 1953.
[3] Pine Flat Lake data taken from Strohschein 1959.
[4] Yearly catch parameters developed from creel census conducted from February 1957 through January 1958.

exploitation rates are low (Rawstron 1967). However, the few anglers using efficient methods were able to catch catfish at a relatively high rate (Figure 4, Appendix I). This finding suggests that a program designed to educate anglers on catfish distribution and angling methods may increase the utilization of these lightly exploited populations. Generally, these data indicate that large warmwater impoundments in central and northern California can sustain greater use and point up the value of programs designed to improve access.

While most segments of the Folsom Lake fishery can probably support greater angling pressure, evidence indicates that the black basses may be over-harvested in relation to competing centrarchid species. Based on tagging studies, Rawstron (1967) found exploitation rates for largemouth bass and bluegill at Folsom Lake to be 0.40 and 0.37, respectively. While these values are similar, the relatively high exploitation rate recorded for bluegill may be a reflection of the size of fish selected for tagging. Tagged bluegill ranged from 6.0 to 9.5 inches and averaged 7.4 inches. The bluegill catch, however, averaged only 5.6 inches. Since large bluegill are probably harvested at a much greater rate than smaller ones, Rawstron's values may be biased on the high side. The largemouth bass tagged at Folsom Lake averaged 11.8 inches which compared favorably to the mean length of 11.7 inches in the catch.

Centrarchid tagging studies at Millerton Lake in 1950 (Fisher 1953) which included bluegill as small as 5.0 inches indicated that largemouth bass were harvested at a rate about four times greater than bluegill. A creel census conducted in the same year (Abell and Fisher 1953) revealed that largemouth bass anglers and bluegill anglers comprised 26 and 46%, respectively, of all fishermen interviewed. At Folsom Lake in 1962, however, efficient bass anglers comprised about 38% of the total recorded effort as compared to only 21% for efficient bluegill anglers. These data strongly suggest that the black basses at Folsom Lake in 1962 were subjected to considerably greater angler pressure and exploitation than the lesser centrarchids.

A continued harvest of black basses at greater rates than competing species unquestionably contributes to the problems of bluegill overabundance and limited bass production so often seen. The result of such selective fishing has been astutely observed by Murphy (1966): "It follows, and has been demonstrated in theory and in experiment that selective fishing (probably the usual case) will always alter the equilibrium state of the population to the disadvantage, if not extinction, of the selected fish and, by definition, to the disadvantage of the angler." This phenomenon may explain the decline in the warmwater segment of the Folsom Lake fishery previously noted. If this is true, management measures are required at Folsom Lake which would decrease bass harvests and increase the exploitation of other segments of the fishery.

An unattractive feature of the 1962 Folsom Lake fishery was the absence of an easily caught game fish to satisfy high angling demand during the spring months (Figures 1, 2, and 3). High angling pressure in the spring is characteristic of many waters, and management efforts should be directed at providing an attractive fishery at that time of year. The introduction of kokanee in recent years has partially solved this problem but this species requires specialized angling techniques

and is normally not available to shore anglers. Shore fishermen were an important segment of the Folsom Lake fishery in 1962, comprising about 40% of the total estimated use. The introduction of black crappie, white crappie, and threadfin shad (*Dorosoma petenense*) could provide an attractive spring fishery for both boat and shore anglers. The value and uniqueness of the present kokanee fishery should be very carefully considered before such introductions are made, however, since it will probably not be possible to manage Folsom Lake with kokanee after threadfin shad become established.

ACKNOWLEDGMENTS

The creel census was designed and implemented by Harold K. Chadwick. Robert R. Rawstron, Robert C. Tharratt, Don A. LaFaunce, Michael Johnson, and various seasonal aids collected most of the census data. Bob Reavis provided the census data for Folsom Lake in the years subsequent to 1962. Data from Clear Lake were obtained from Larry Puckett. Alex Calhoun and Robert Elwell critically reviewed the manuscript and offered many helpful suggestions. Thanks are extended to Patrick Tomlinson who prepared the computer program for data analysis.

REFERENCES

Abell, Dana L. and Charles K. Fisher. 1953. Creel census at Millerton Lake, California, 1945–1952. Calif. Fish Game 39(4): 463–484.

Beland, R. D. 1960. History of the El Capitan Reservoir fishery, San Diego County. Calif. Dep. Fish and Game, Inland Fish. Admin. Rep. 60-20, 31 p.

Bell, Robert R. 1952. The fishery of Vail Reservoir, Riverside County; a preliminary report. Calif. Dep. Fish and Game, Inland Fish. Admin. Rep. 52-24, 2 p.

Fisher, Charles K. 1953. The 1950 largemouth black bass and bluegill tagging program in Millerton Lake, California. Calif. Fish Game 39(4): 485–487.

Grosslein, Marvin Darrel. 1962. Estimation of angler harvest on Oneida Lake, New York. Ph.D. thesis, Cornell Univ., Ithaca, 296 p.

Jenkins, Robert M. 1968. The influence of some environmental factors on standing crop and harvest of fishes in U. S. reservoirs. *In:* Reservoir Fishery Resources Symposium. Athens, Georgia. April 5–7, 1967. 298–321.

Jessen, R. J. 1956. Comments and suggestions on designing creel censuses. *In*: Symposium on sampling problems in creel census, Iowa Coop. Fish. Res. Unit, Ames, p. 50–56.

Kimsey, J. B. 1958. Fisheries problems in impounded waters of California and the lower Colorado River. Am. Fish. Soc., Trans. 87:319–332.

LaFaunce, Don A., J. B. Kimsey, and Harold K. Chadwick. 1964. The fishery at Sutherland Reservoir, San Diego County, California. Calif. Fish Game 50(4): 271–291.

McCammon, G. W. 1953. Lake Wohlford, San Diego County, catch record analysis, 1950–52. Calif. Dep. Fish and Game, Inland Fish. Admin. Rep. 53-6, 10 p.

Murphy, Garth I. 1966. Population dynamics and population estimation, p. 1–18. *In*: Alex Calhoun (ed.) Inland Fisheries Management. Calif. Dep. Fish and Game.

Rawstron, Robert R. 1964. A limnological survey of selected California reservoirs. Calif. Dep. Fish and Game, Inland Fish. Admin. Rep. 64-3, 7 p.

———. 1967. Harvest, mortality, and movement of selected warmwater fishes in Folsom Lake, California. Calif. Fish Game 53(1): 40–48.

Strohschein, W. E. 1959. Pine Flat Reservoir creel census study, 1955–1958. Calif. Dep. Fish and Game, Inland Fish. Admin. Rep. 59-6, 18 p.

Tharratt, Robert C. 1966. The age and growth of centrarchid fishes in Folsom Lake, California. Calif. Fish Game 52(1): 4–16.

von Geldern, Charles E., Jr. 1964. Distribution of white catfish, *Ictalurus catus* and rainbow trout, *Salmo gairdneri*, in Folsom Lake, California, as determined by gill netting from February through November 1961. Calif. Dep. Fish and Game, Inland Fish. Admin. Rep. 64-15, 9 p.

APPENDIX I. **Catch Rates and Catch Compositions of Fishermen Using Various Angling Techniques at Folsom Lake, 1962.**

Angling method	Boat(B) Shores(S)	Hours fished	Bass		Sunfish		Catfish		Rainbow trout		All species	
			Catch per hour	Percent of total	Catch per hour	Percent of total	Catch per hour	Percent of total	Catch per hour	Percent of total	Catch per hour	Percent of total
Troll	B	881	0.10	59.3	0.01	3.9	Tr.*	1.3	0.06	35.5	0.18	100.0
Lures	B	1,890	0.18	81.3	0.01	4.3	Tr.	0.5	0.02	10.9	0.21	100.0
	S	921	0.16	83.8	0.03	14.0	Tr.	1.7	Tr.	0.6	0.19	100.0
Minnows	B	2,784	0.23	81.1	0.01	12.5	0.01	2.1	0.01	4.1	0.28	99.8
	S	2,116	0.16	78.7	0.02	8.1	Tr.	2.6	0.02	10.5	0.20	99.9
Minnows and lures	B	850	0.17	81.3	0.03	15.9	Tr.	1.1	Tr.	1.7	0.21	100.0
	S	491	0.18	86.3	0.01	5.9	0.01	6.9	Tr.	1.0	0.21	100.0
Worms	B	1,551	0.08	11.8	0.50	77.0	0.07	10.8	Tr.	0.4	0.65	100.0
	S	3,713	0.05	7.7	0.49	80.5	0.07	15.6	Tr.	0.4	0.61	99.8
Worms and lures	B	436	0.07	20.4	0.22	68.3	0.03	10.6	Tr.	0.7	0.33	100.0
	S	571	0.11	32.8	0.21	62.4	0.01	3.7	Tr.	1.1	0.33	100.0
Worms and minnows	B	1,117	0.09	32.7	0.16	58.4	0.02	8.3	Tr.	0.6	0.28	100.0
	S	2,006	0.07	31.4	0.12	54.9	0.02	12.7	Tr.	1.2	0.21	100.2
Sardines	B	129	0.02	3.9	0.01	1.3	0.57	91.9	0.00	0.0	0.60	100.1
	S	100	0.01	3.7	0.03	11.3	0.22	81.9	0.00	0.0	0.26	99.9
Sardines and worms	B	129	0.00	0.0	0.03	8.1	0.35	91.9	0.00	0.0	0.38	100.0
	S	592	0.02	6.1	0.12	43.6	0.13	49.1	Tr.	0.6	0.26	100.0
Lures, minnows, and worms	B	261	0.12	66.0	0.06	31.9	Tr.	2.1	0.00	0.0	0.18	100.0
	S	219	0.10	18.8	0.08	41.9	0.01	1.6	0.01	4.7	0.20	100.0
All others	B	2,012	0.10	33.5	0.11	45.0	0.02	7.9	0.01	13.7	0.30	100.1
	S	1,525	0.06	24.1	0.15	59.5	0.01	13.2	0.01	3.0	0.26	100.1
All methods	B	12,073	0.14	45.0	0.12	40.0	0.03	9.0	0.02	5.9	0.31	99.9
	S	12,884	0.09	25.8	0.20	59.3	0.04	13.0	0.01	1.9	0.34	100.0
Total	B & S	24,957	0.11	34.7	0.16	50.3	0.04	11.2	0.01	3.9	0.33	100.1

* Tr. <0.005.

Calif. Fish and Game 58(2): 94–101. 1972

WHITE STURGEON POPULATION CHARACTERISTICS IN THE SACRAMENTO-SAN JOAQUIN ESTUARY AS MEASURED BY TAGGING[1]

LEE W. MILLER
Anadromous Fisheries Branch
California Department of Fish and Game

Exploitation rates were 0.073 and 0.065 for 1967 and 1968. These rates empirically seem low enough to provide adequate protection under existing regulations of one 40-inch sturgeon per angler day.

Shedding of tags under the anterior portion of the dorsal fin was negligible, but shedding was significant for tags under the posterior portion of the dorsal fin. Most tag shedding occurred after the first year.

The percentages of total tag returns returned by anglers using private boats, anglers fishing from party boats and shore anglers were 74.1, 20.5 and 5.4% respectively.

The population size was estimated at 114,667 sturgeon. The 95% confidence interval was 72,384 to 212,293.

INTRODUCTION

The white sturgeon (*Acipenser transmontanus*) population declined drastically in the late 19th and early 20th centuries, probably due to excessive commercial fishing. Both the commercial and sport fishery were closed in 1917. The population had recovered by 1954 so that a sport fishery could be initiated. Pycha (1956) and Chadwick (1959) studied white sturgeon to evaluate exploitation rates and describe its life history. Chadwick reported exploitation rates between 2 and 10%. A precise estimate was not obtainable due to tagged fish being taken in commercial gear incidental to salmon and shad fishing. There was also no measure of nonresponse.

From 1954 through 1963 anglers had no effective technique for catching sturgeon, except for snagging which was prohibited in 1956. In 1964, anglers started using bay shrimp (*Crago* sp.) which greatly increased angling efficiency. This tagging study was initiated to determine the impact of the new fishing techniques on the harvest rate. Returns are no longer influenced by commercial fishing as none is permitted in the Sacramento-San Joaquin estuary with gear which could capture sturgeon.

TAGGING METHODS

An 8-inch trammel net was drifted in San Pablo Bay (Figure 1). Drifts lasted 15 min to 1 hr. Sturgeon were removed from the net, placed in cradles and tagged with disc dangler tags using methods described by Chadwick (1963).

[1] This work was financed by Dingell-Johnson Project California F-9-R, "A Study of Sturgeon and Striped Bass," supported by Federal Aid to Fish Restoration Funds. Accepted for publication January 1972.

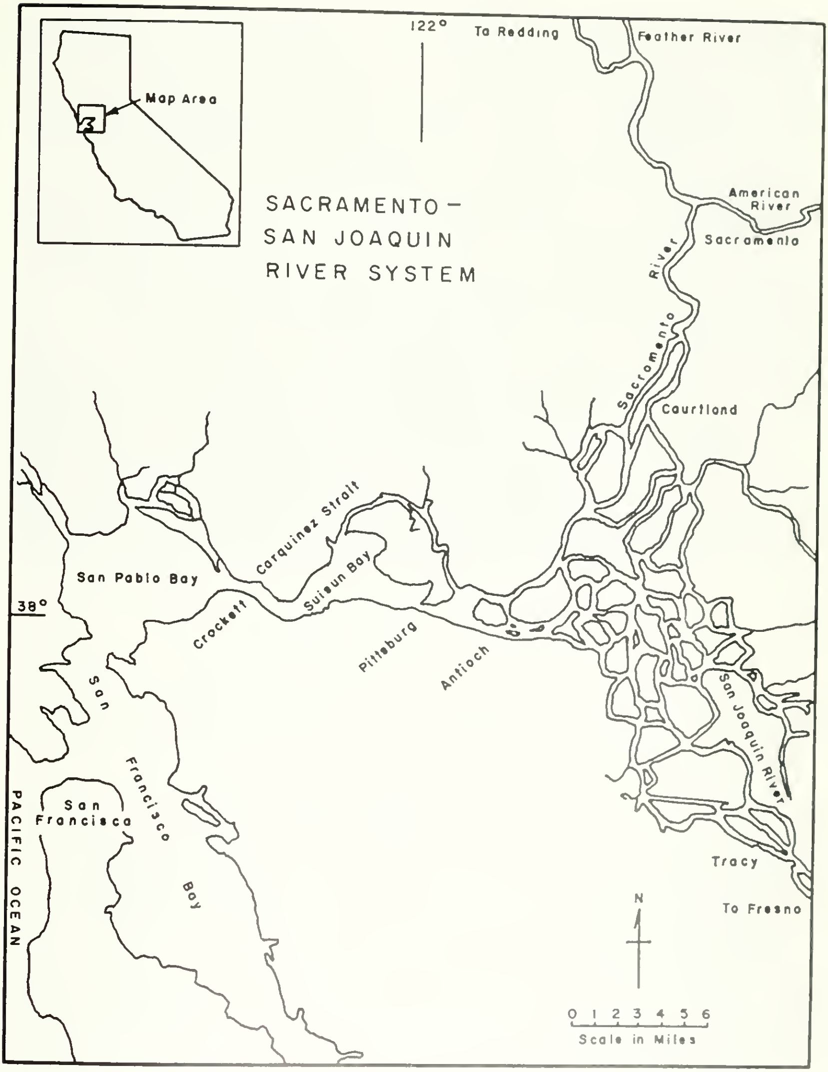

FIGURE 1. Map of the study area. Tagging was done in San Pablo Bay.

Five-dollar reward tags were used exclusively to assure a high response from anglers catching tagged sturgeon. Approximately one-half of the fish were double-tagged to determine tag shedding rates. Tags were placed through the upper back below the anterior and posterior end of the dorsal fin (locations A and B respectively, see Figure 2). Approximately one-fourth of the fish were single-tagged at A only, and one-fourth at location B only. The A location was empirically better because the muscle mass at that location is large and firm.

Only fish longer than the 40-inch TL minimum size limit were tagged.

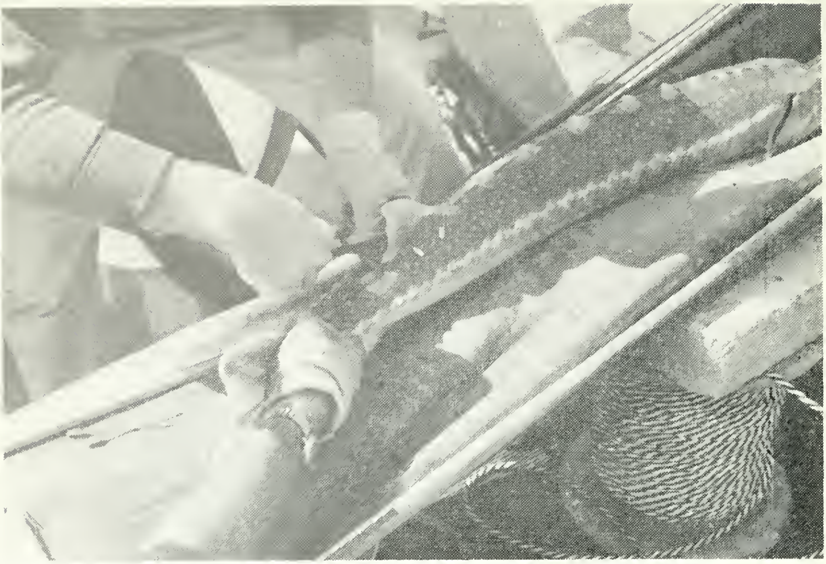

FIGURE 2. White sturgeon being double tagged with disc dangler tags. The anterior tag is designated tag A, the posterior tag B.

RESULTS

In 1967, 1,612 sturgeon were tagged and in 1968, 1,080 sturgeon were tagged. The mean size of sturgeon tagged in 1967 was 47.0 inches and in 1968, 48.8 inches (Figure 3).

Effect of Condition on Returns

To evaluate handling induced mortality, the condition of each sturgeon was classified subjectively as good, fair or poor depending upon the vigor of the sturgeon's swimming efforts upon release.

Surprisingly the fish in fair or poor condition had significantly higher returns than those in good condition.

The only direct evidence of mortality was one tagged sturgeon found dead along the shore of San Pablo Bay. Undoubtedly there were some other mortalities but the general hardy nature of sturgeon is favorable to their withstanding the stress.

Tag Shedding

Returns from double-tagged fish were combined for 1967 and 1968 and revealed significant shedding (Figure 4). A few tags in the B position were shed during the first 360 days. However, during the interval 360–480 days, the shedding rate increased dramatically so that of the 39 double-tagged returns, 18 had shed the B tag. The A tag shedding rate was much less than the B rate and remained at a low rate throughout the study period (Figure 4). Only 6 tags of 198 returns received to date were shed.

Probabilities of tags being shed were calculated using the formulas of Gulland (1963). The probability for A tag shedding was 0.011 for the first 360-day period; 0.017 for the first 720 days and 0.024 for the

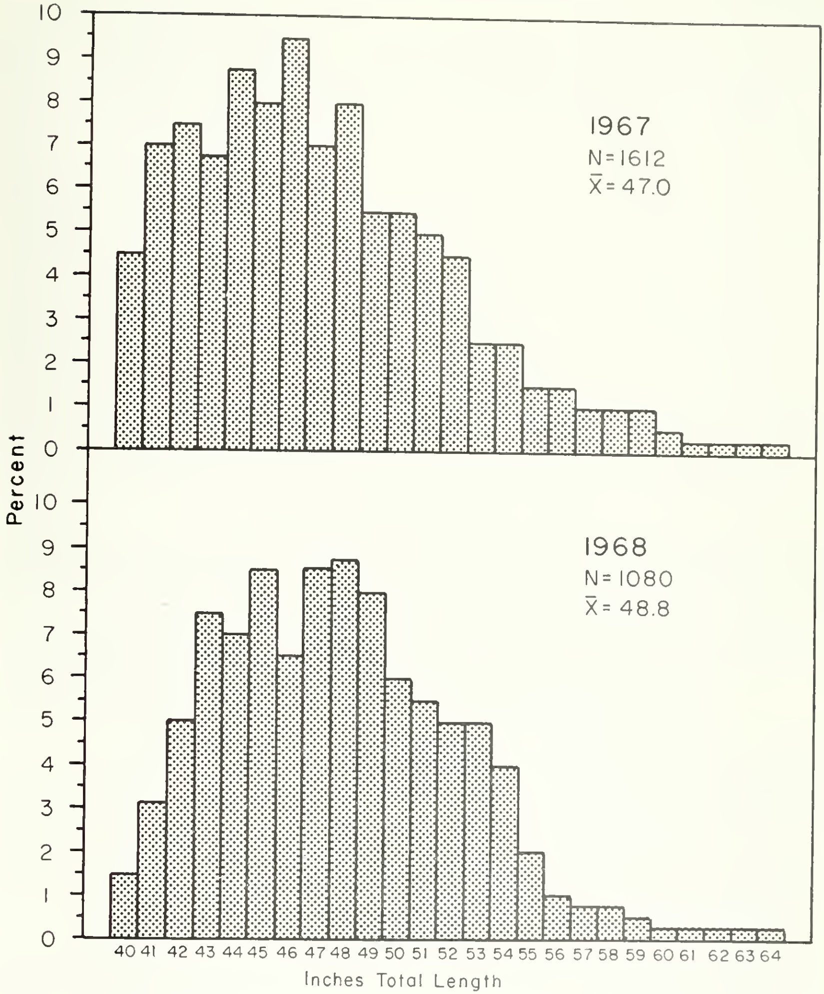

FIGURE 3. Length frequency of sturgeon tagged in 1967 and 1968.

first 1,080 days. The probability of B tag loss was 0.057 for the first 360-day period; 0.314 for the first 720-day period and 0.500 for the 1,080-day period.

The shedding of B tags after 1 year was undoubtedly a function of the time required to wear a hole through the flesh at that location. The A position was at a much thicker cross section of the body. Hence, A tags remained attached fairly well through the first 1,080 days.

The ratio of returns from single A tagged to single B tagged fish generally increased with time, indicating the shedding of the B tags (Table 1). This corroborates the data developed in the double tagging experiment.

A pertinent use of the single tags is to examine the possibility that double-tagged fish suffer an increase in mortality due to the extra stress

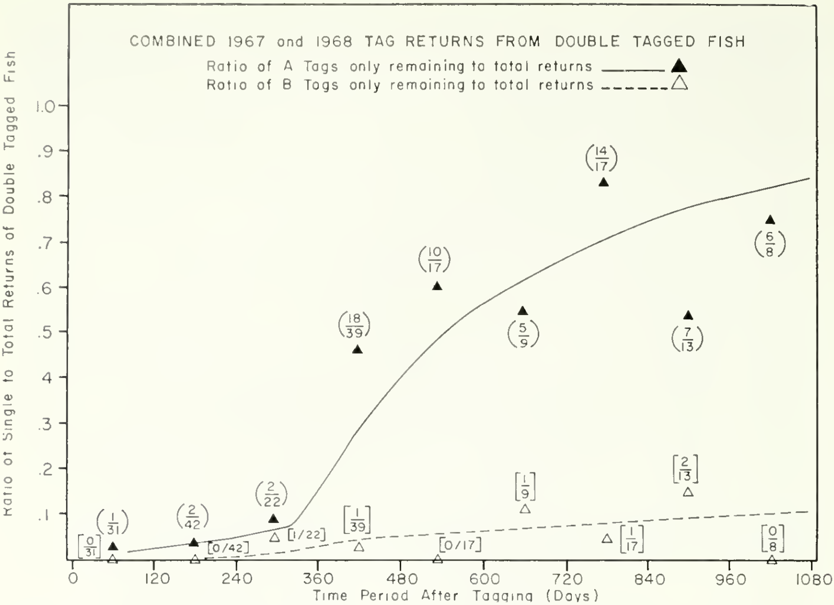

FIGURE 4. Rate of shedding illustrated from returns from fish which were double tagged in 1967 and 1968. Shedding rates during 120-day intervals are indicated by ratios of returns from fish with one tag shed to total returns from double tagged fish regardless of which tags remained. Ratios in parenthesis indicate the number returned.

of having two tags. The returns from single A tags and double-tagged fish with A tags still attached were compared with the expected returns based on the numbers of single and double-tagged fish released. A similar comparison was made for B tags (Table 2). The Chi-square values were not significant indicating that double-tagged fish do not suffer higher mortality than the single-tagged fish.

Exploitation Rate

Only single A and double-tagged fish were used in estimating mortality rates to avoid bias due to the shedding of B tags (Table 3). No correction was made for the slight bias caused by the shedding of A tags. The exploitation rate was 0.073 for 1967 and 0.065 for 1968.

TABLE 1. **Comparison of Single B to Single A Tag Returns from the 1967 and 1968 Tagging Combined.**

	Interval (days)					
	0–240	241–480	481–720	721–960	961–1200	Total
Single A	31	24	18	13	4	90
Single B	34	23	7	6	0	70
Ratio A/B	.91	1.04	2.57	2.17	--	1.29

TABLE 2. **Comparison of Single Tag to Double Tag Returns for A and B Tags from the 1967 Tagging.**

Tags	Tags released	Expected returns	Actual returns	χ^2	Tags	Tags released	Expected returns	Actual returns	χ^2
A	414	69.7	64	--	B	400	45.4	46	--
AB	798	134.3	140	--	AB	798	90.6	90	--
Total	1,212	204	204	0.2157	Total	1,198	136	136	0.0026

Survival in 1967 was estimated to be 0.862 using Ricker's (1958) formula 4.1, so the estimated annual expectation of natural death for 1967 is 0.065.

Mean first year return rates for 1967 and 1968 combined were 7.0% for fish less than 45 inches, 5.8% for fish 46–50 inches, and 7.2% for fish greater than 51 inches long. These percentages do not differ significantly indicating that exploitation rate is not related to fish size.

Characteristics of the Fishery

A postcard questionnaire was sent to each angler returning tags to determine if they were fishing from a party boat, private boat or shore. These tabulations (Table 4) show that anglers fishing from private boats dominated the fishery (74.1%). Party boats are of secondary importance (20.5%), and shore anglers contribute a small portion of the total returns (5.4%).

TABLE 3. **Tabulation of Tag Release and Recapture Data.**

Year	Tag location	Number released	1st year returns	2nd year returns	U	Confidence limits for (U)
1967	Single A	414	25	26		
	AB	798	62	49		
	Total	1,212	87	75	0.073	0.058–0.088
1968	Single A	292	16	--		
	AB	597	37	--		
	Total	819	53	--	.065	0.049–0.083

TABLE 4. **White Sturgeon Returns by Angler Strata.**

	Party boat		Private boat		Shore		Total
	N	%	N	%	N	%	
1967–68	13	11.5	93	82.3	7	6.2	113
1968–69	42	28.6	97	66.0	8	5.4	147
1969–70	12	19.3	49	79.0	1	1.6	62
1970–71*	5	17.2	21	72.4	3	1.0	29
Total	72	20.5	260	74.1	19	5.4	†351

* Includes data received through 8–17–71.
† A total of 366 returns were received, 15 of which (4 %) did not respond to the questionnaire.

Sturgeon Population Estimate

A crude estimate of the number of sturgeon in the population in the fall of 1967 can be made by analyzing tags recaptured during tagging operations in 1968. The following data were used:

M = 1,612 (number of fish tagged in 1967).
R = 14 (number of tagged fish recaptured during 1968 tagging).
C = 1,066 (number of fish caught in 1968 that were 41 inches or greater in length to adjust for recruitment since sturgeon average about 1 inch of growth per year) (Miller and Orsi, unpublished data).

$$N = \frac{M(C + 1)}{(R + 1)} = 114{,}667$$

The 95% confidence interval for the estimate was calculated using the Poisson Variable Table in Fryer (1966). The confidence interval is 72,384–212,293.

DISCUSSION

Ricker (1958, p. 86) lists a series of conditions which must be met to obtain unbiased estimates of mortality rates and population size from mark and recapture studies. The use of reward tags, the measurement of low tag shedding rates, and the indication that rate of return is not decreased by fatigue suffered during tagging indicate that most conditions are met. The only condition which may not be met is that either tagged fish must become randomly mixed in the population or the distribution of effort must be proportional to the number of fish present in different areas.

The estimated population size in 1967 is much larger than the crude estimate of 11,154 sturgeon in San Pablo Bay in 1954 (Pycha, 1956). The 1954 estimate is almost certainly underestimated by repeated sampling in one place before tagged fish had time to become randomly mixed in the population. However, the general magnitude of the difference suggests an increase in population size since 1954. Vincent Catania, our netman who was involved in both tagging operations, observed that sturgeon were much easier to catch in 1967 than in 1954, supporting the hypothesis that the population was larger.

The exploitation rates empirically do not appear to be excessive although there are many factors which need to be known before estimates of sustained yield can be obtained. It would seem from these data that angling is a relatively inefficient means of harvesting which provides sufficient protection to the population. Hence, present regulations of one 40-inch or larger sturgeon per angler day appear to be adequate to protect the population under existing conditions.

ACKNOWLEDGMENTS

The efforts of Vincent Catania (deceased), Robert J. McKechnie, Richard Fenner and Ratzi Mercurio contributed to the success of our tagging program. H. K. Chadwick made many helpful suggestions.

REFERENCES

Chadwick, Harold K. 1959. California sturgeon tagging studies. Calif. Fish Game 45(4): 297–301.

——— 1963. An evaluation of five tag types used in a striped bass mortality rate and migration study. Calif. Fish Game 49(2): 64–83.

Fryer, H. C. 1966. Concepts and methods of experimental statistics. Allyn and Bacon, Inc., Boston. 602 p.

Gulland, J. A. 1963. On the analysis of double-tagging experiments. *In*: North Atlantic Fish Marking Symposium, Spec. Publ. No. 4. Inter. Comm. for the Northwest Atlantic Fisheries, p. 228–229.

Pycha, Richard L. 1956. Progress report on white sturgeon studies. Calif. Fish Game 42(1): 23–35.

Ricker, W. E. 1958. Handbook of computations for biological statistics of fish populations. Fisheries Research Board of Canada, Bull. 119, 300 p.

Calif. Fish and Game 58(2): 102–106. 1972.

MIGRATIONS OF STURGEON TAGGED IN THE SACRAMENTO-SAN JOAQUIN ESTUARY[1]

LEE W. MILLER
Anadromous Fisheries Branch
California Department of Fish and Game

A total of 2,692 white sturgeon (*Acipenser transmontanus*) and 54 green sturgeon (*Acipenser medirostris*) were tagged in 1967 and 1968. Tag returns from white sturgeon indicate that the population inhabits the lower estuary during the summer, fall and winter. An apparent spawning migration occurs during late winter and spring. Two green sturgeon were recaptured at the mouth of the Columbia River, one in Washington, one at Santa Cruz and one in the estuary.

INTRODUCTION

Tagging of sturgeon in 1954 (Chadwick, 1959) revealed very little concerning white sturgeon migration. One white sturgeon tagged in San Pablo Bay was caught at the mouth of the Columbia River 294 days later. All other tag returns from white sturgeon were from San Pablo Bay to the confluence of the Sacramento-San Joaquin rivers. No upstream returns were obtained. Twenty-five green sturgeon were tagged in 1954. Three tags were returned from Oregon (Chadwick, 1959).

In 1967, we tagged 1,612 white surgeon and 26 green sturgeon. In 1968, we tagged 1,080 white sturgeon and 28 green sturgeon. Most of the tagging was done in San Pabo Bay. All sturgeon tagged were legal sized fish, 40 inches TL or larger. For a description of tagging methods, see Miller (1972).

MIGRATION OF WHITE STURGEON

A total of 341 white sturgeon tag returns have been received. This includes 3 years of 1967 tags and 2 years of returns from the 1968 tagging. Returns were tabulated according to the areas designated in Figure 1. All years of returns were combined since differences between years could not be ascertained due to the small number of returns in any year and area. Defining migrations by such tabulations has inherent drawbacks because the fishery probably does not always reflect the abundance of fish in a given area.

Over 73% of the tag returns were received from the Suisun and San Pablo areas (Areas 6 and 7), Table 1. The fishery in these areas exists throughout the year, but is concentrated in the period from November to March. Over 63% of the returns from these two areas were received during these 5 months. Sturgeon returns from the Delta (Area 9) were only 3% of the total and were concentrated in the winter and spring months.

[1] This study was performed as part of Dingell-Johnson Project California F9R, "A Study of Sturgeon and Striped Bass", supported by Federal Aid to Fish Restoration Funds. Accepted for publication November 1971.

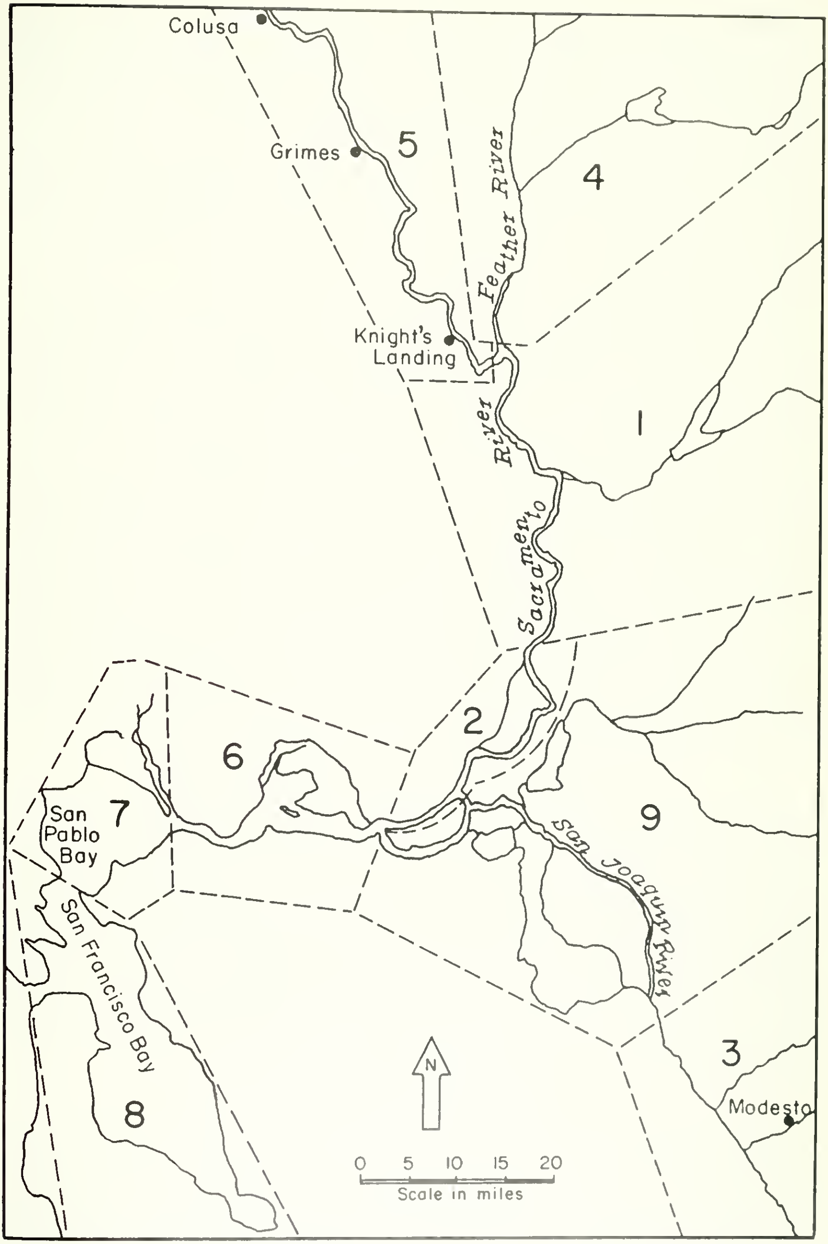

FIGURE 1. The Sacramento-San Joaquin estuary showing tag return areas.

Many sturgeon appear to migrate to the lower Sacramento River (Area 2) in the winter prior to the spawning season and move on up the Sacramento River (Areas 1 and 5) from March through June. Returns from the upper Sacramento River were scattered between the mouth of the Feather River and Colusa.

This time period agrees well with known spawning times determined by sampling larvae (Stevens and Miller, 1970). Larvae were caught in the Sacramento River system from March 28 to May 21, 1968. Tag returns from the upper Sacramento River ranged from March 26 to May 11, 1968.

The average size of fish caught in the upstream areas was nearly 52 inches TL at tagging which is about 4 inches above the average size of the tagged population. It is not known at exactly what size sturgeon become sexually mature although we have found female sturgeon mature at 45 inches. The likelihood of being mature increases with size and age so it is not surprising that the average size of fish caught in the spawning area is larger than the population mean size.

Tag returns suggest that the Sacramento River is the major spawning area for the white sturgeon. The fact that one sturgeon was caught in the Feather River in April indicates that spawning may occur there. The San Joaquin River may have been an important spawning area prior to its degradation by man. In 1968 flows were low in the San Joaquin River when the two sturgeon were caught there. One of these sturgeons was caught 7 miles north of Modesto and the other 3 miles south of San Joaquin City. No sturgeon larvae were caught in the San Joaquin River in the spring of 1968 during some exploratory sampling.

MIGRATION OF GREEN STURGEON

Of the 54 green sturgeon tagged, 5 returns were received. Four of these fish were tagged in October 1967 and were recaptured by commercial fishermen. They ranged from 45 to 50 inches TL at tagging. The dates and localities of recapture were December 28, 1967 near Santa Cruz, California; September 20, 1968 at the mouth of the Columbia River; July 25, 1969 at Gray's Harbor, Washington; and August 17, 1970 at Astoria, Oregon. The return from Gray's Harbor is the farthest north of all returns received from green sturgeon tagged in San Pablo Bay. One green sturgeon tagged in October 1967 was recaptured in San Pablo Bay on January 1, 1971.

CONCLUSIONS

White sturgeon appear to be confined principally to the estuary, spending the summer, fall and winter in the lower bays and Delta. The fish which are going to spawn migrate upstream during February, March, April and May, then return downstream. Green sturgeon returns corroborate previous findings (Chadwick, 1959) that they spend more time in the ocean than white sturgeon and move considerable distances along the coast. It is not known whether green sturgeon spawn in the Sacramento-San Joaquin system, but 10 to 20-inch juveniles are common in the Delta (Radtke, 1966).

TABLE 1. **White Sturgeon Tag Returns by Area and Month**

	Sacramento River	Lower Sacramento River	San Joaquin River	Feather River	Upper Sacramento River	Suisun Bay	San Pablo Bay	San Francisco Bay	Delta	Total
Area number	1	2	3	4	5	6	7	8	9	
November	2	3	--	--	--	24	15	--	--	44
December	--	4	--	--	--	12	14	--	1	31
January	--	5	--	--	--	14	24	1	2	46
February	1	12	--	--	--	6	24	2	2	47
March	1	4	2	--	1	3	23	6	--	40
April	8	1	--	1	5	1	12	1	1	30
May	4	--	--	--	2	1	5	--	2	14
June	2	--	--	--	1	5	6	--	1	15
July	--	--	--	--	--	7	7	--	--	14
August	--	1	--	--	--	11	3	--	1	16
September	1	2	--	--	--	13	2	--	--	18
October	--	6	--	--	--	16	4	--	--	26
Total	19	38	2	1	9	113	139	10	10	341
Percent of total	5.6	11.1	.6	.3	2.6	33.1	40.8	2.9	2.9	

REFERENCES

Chadwick, H. K. 1959. California sturgeon tagging studies. Calif. Fish Game 45(4): 297–301.

Miller, Lee W. 1972. White sturgeon population characteristics in the Sacramento-San Joaquin estuary as measured by tagging. Calif. Fish Game 58(2): 94–101.

Radtke, Larry D. 1966. Distribution of smelt, juvenile sturgeon, and starry flounder in the Sacramento-San Joaquin Delta with observations on food of sturgeon, pages 115–129. *In*: Turner, Jerry L. and D. W. Kelley, compilers. Ecological studies of the Sacramento-San Joaquin Delta, Part II, Fishes of the Delta, Calif. Fish and Game, Fish Bull. 136.

Stevens, Donald E. and Lee W. Miller. 1970. Distribution of sturgeon larvae in the Sacramento-San Joaquin River system. Calif. Fish Game 56(2): 80–86.

Calif. Fish and Game 58(2): 107–115. 1972.

MOLTING AND GROWTH IN LABORATORY REARED PHYLLOSOMES OF THE CALIFORNIA SPINY LOBSTER, *PANULIRUS INTERRUPTUS*[1]

DEBORAH M. DEXTER
Department of Zoology
San Diego State College
San Diego, California 92115

Phyllosome larvae of the California spiny lobster were reared in individual, multiple, and mass cultures in laboratory closed circuit sea water systems. Laboratory-reared larvae progressed through six phyllosomal stages in a series of eight molts. Maximum length of larval life in the laboratory was 114 days; gradual mortality indicated that nutritional factors were the likely cause of death.

INTRODUCTION

The intent of this study was to rear the larvae of *Panulirus interruptus* through its 11 phyllosomal stages in the laboratory. Attempts at laboratory rearing of spiny lobster phyllosome larvae have generally been limited in their success. The only spiny lobster that has been successfully reared through its complete phyllosomal development in the laboratory is *Scyllarus americanus* (Robertson, 1968). No palinurid phyllosomes have ever been carried in the laboratory through their complete larval development. In this study sequence of larval stages, duration of stages, and number of molts within each stage were carefully followed. Particular attention was given to the effects of temperature and food on larval development and survival.

MATERIAL AND METHODS

Equipment

Closed circuit sea water systems were used in this study. Plywood tanks, coated with black fiberglass resin, measuring 1.5 m x 0.6 m x 0.2 m, were used as culture tanks for individual and multiple cultures of phyllosome larvae. Two corner filters containing glass wool and charcoal were placed in each of these 132 liter (35 gallon) tanks. An ultraviolet sterilizing unit was attached to a dynaflow filter containing calcium carbonate chips, charcoal, and glass wool, so that water was both filtered and sterilized before returning to the tank (Figure 1). Oyster shell fragments were scattered over the tank bottom to maintain a basic pH. Large scale aeration of the tank was obtained by using a 2 cm diameter PVC tube, 1.2 m long, into which a series of small holes had been drilled. A stainless steel rod, sealed in rubber surgical tubing, was placed inside the air tube to keep it on the bottom of the tank. Small 25 watt heaters were used to maintain tanks at 25 C, while other tanks were kept at ambient room temperature (20 C). Black

[1] Accepted for publication November 1971. This research was supported by the Office of Sea Grant Programs, Project GH-36, under the auspices of the National Science Foundation.

plexiglass sheeting was placed over each tank to reduce water evaporation and to prevent foreign material from falling into the tank. Offshore coastal water was collected, filtered through a Buchner funnel, and added to the tanks.

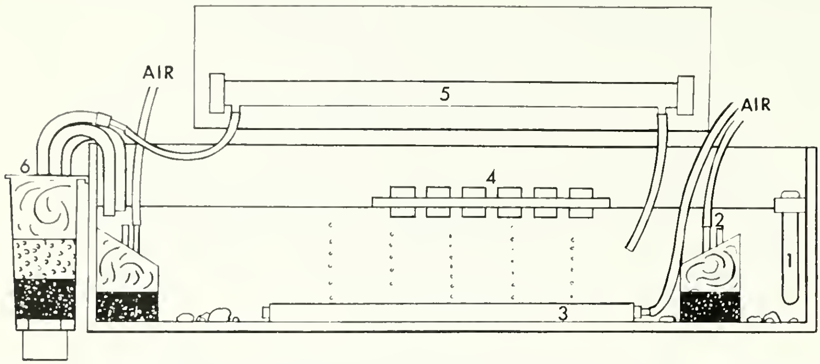

FIGURE 1. Laboratory apparatus used for culturing phyllasome larvae. Drawing not to scale. 1 aquarium heater 2 corner filter 3 aeration tube 4 plastic culturing dishes in styrofaam floats 5 ultravialet sterilizing unit 6 large dynaflow filtering unit

Four planktonkreisels, similar to those designed by Greve (1968) were used for mass culture of phyllosomes. These consisted of round 5 gallon glass containers with an air outlet in a central column. Supplemental air jets at the sides of the container caused a continuous rotation of water thus maintaining the phyllosomes in a slow, circular motion. The planktonkreisels were also provided with subsurface sand filters.

Containers used in individual and multiple cultures were similar to the compartmentalized plastic trays of Modin and Cox (1967) with the added advantage that each container could be removed and examined separately. Plexiglass tubing, 2 cm, 2.5 cm, 4 cm, 5.5 cm, and 6 cm, in diameter, was cut into 3.2 cm lengths. Small windows were made in the sides of the four larger tubes. Nylon netting, mesh size of 253 microns, was glued with silicone cement to the bottom and windows of these containers. Smaller containers were used for Stage I and Stage II phyllosomes; larger containers were used for older larvae and for multiple cultures. The containers were leached in fresh water for at least 48 hr before being used. The containers were placed into styrofoam sheets 30 cm x 10 cm x 1 cm which were floated on the suface of the water.

Maintenance

Berried females were kept in running sea water tanks in the Scripps Institution of Oceanography Experimental Aquarium and fed on *Mytilus*. Released phyllosomes were brought from Scripps to the San Diego State College laboratory where they were introduced into individual, multiple, or mass culture. *Artemia* nauplii provided the main food source during this study. There is considerable variation in growth and survival of phyllosomes in regards to source of *Artemia*. The most

successful batches were reared using *Artemia* (Lot #5200) from the Chaplin Brine Shrimp Co. Ltd., Chaplin, Saskatchewan, Canada. Short-term feeding experiments were conducted using *Mytilus* gonad, *Lytechinus* eggs, and ctenophores, chaetognaths, and fish larvae from fresh plankton tows. Phyllosomes were fed daily. Temperature, salinity, and pH of the systems were monitored twice weekly.

Approximately 1,800 phyllosomes were followed individually in the small plexiglass containers. These were checked daily to determine their condition, stage, and molting frequency. About 5,000 larvae were placed in multiple culture dishes of 5 to 15 animals per dish. As larvae died off in the individual containers, they were replaced with larvae from multiple cultures. Mass culture was attempted using planktonkreisels on about 20,000 phyllosomes.

Four batches of phyllosomes were followed in this study. October phyllosomes were divided into two groups; some were reared at 25 C and others at ambient room temperature. Effects of food type on survival were examined by following 240 phyllosomes fed on *Artemia* nauplii, *Mytilus* gonad, or *Tubifex*, and kept at ambient room temperature. April, June, and July batches of phyllosomes were reared at 25 C on *Artemia* nauplii. A wider variety of food sources fed to 383 phyllosomes hatched in June and July allowed additional comparisons on the relationship between food type and survival.

Preserved larvae were measured with an ocular micrometer under a dissecting microscope to determine growth in size with time. Size measurements were made on length of the cephalic shield, thorax, and abdomen combined, and width of the cephalic shield. Attempts to measure preserved molts were unsuccessful.

RESULTS

Stages and Molts

Johnson (1956) described and illustrated 11 phyllosomal stages of *Panulirus interruptus*. These descriptions were based on preserved plankton material and could not take into account the dynamics of growth, either with respect to duration of stages or number of molts within stages. The laboratory stages observed in this study paralleled those described by Johnson and were subscripted to identify molts within the stage. The laboratory-reared phyllosomes progressed through 6 stages in a series of 8 molts. Only 1 molt occurred between Stage I and II, II and III, IV and V, and V and VI.

In the laboratory, phyllosomes normally progressed through 4 molts in changing from Stage III to Stage IV. In this series minor morphological changes and slight increases in size were observed with each molt. In Stage IIIa the bud of periopod 4 was barely visible, while in Stage IIIb the bud was about one half the length of the abdomen (Figure 2). In Stage IIIc the bud of periopod 4 was equal in length with the abdomen, and in Stage IIId the bud was longer than the abdomen. In Stage IV the 4th periopod bud is twice the length of the abdomen and the exopod bud is present (Johnson, 1956).

More than 99% of the phyllosomes observed molted directly from Stage IIIa to Stage IIIb. Less than 1% molted from Stage IIIa to IIIc. From Stage IIIb, 81% molted to Stage IIIc, 17% to Stage IIId, and

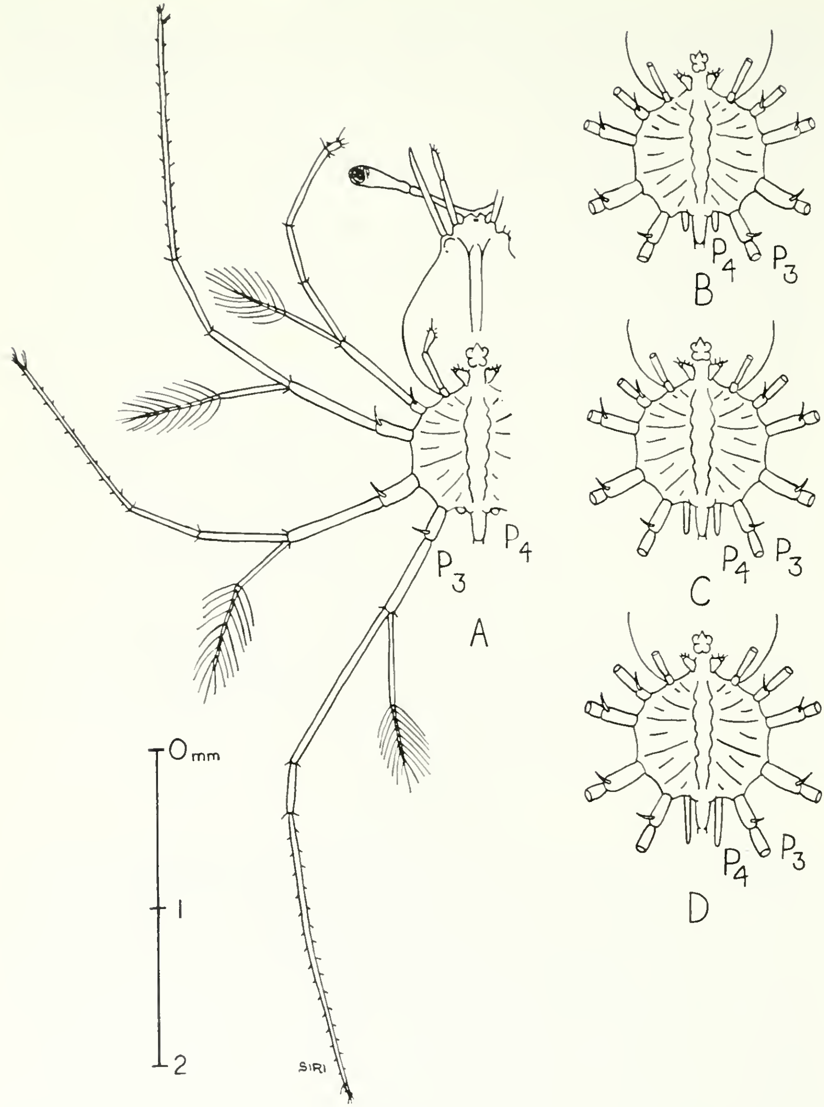

FIGURE 2. Stage III *Panulirus interruptus* phyllosoma
A. Stage III[a] B. Stage III[b] C. Stage III[c]
D. Stage III[d] Labels: P_3 3rd periopod
P_4 4th periopod

2% into Stage IV. Of the phyllosomes entering Stage IIIc, 85% molted to IIId, 11% to Stage IV, and 4% to Stage V. In progressing from Stage III to Stage IV, 92% of the phyllosomes took 4 molts to complete the sequence; 7% spent 3 molts in Stage III, and 1% spent 2 molts in Stage III. It is quite likely that these molting irregularities are strictly a laboratory phenomenon.

Laboratory Survival and Growth

Phyllosomes raised in mass culture in the planktonkreisels survived for a maximum of 20 days. Those in multiple cultures remained healthy for up to 60 days before being transferred to individual containers. Maximum length of life in the laboratory, 114 days, was obtained by the phyllosomes living in individual containers. Mortality was high; approximately 50% of all phyllosomes died between each molt.

It was not possible to accurately measure living phyllosomes. Size determinations on preserved phyllosomes indicate that there is considerable range in size among phyllosomes at the same stage (Table 1). The phyllosomes raised at 25 C grew an average of .5mm/molt compared to those reared at 20 C which grew an average of .3mm/molt. Since these phyllosomes belonged to three different batches, one a fall hatch, the others spring hatches, it is impossible to state whether the size difference was due to the effects of season or temperature. These laboratory-reared phyllosomes are significantly smaller than the phyllosomes collected from the plankton by Johnson (1956).

Molting Frequency

There is considerable variation in duration of stages and molting frequencies among batches hatched during different seasons (Table 2). There is also a significant difference in duration of stages between phyllosomes of the same batch reared at different temperatures (Table 2). Development progressed more rapidly at 25 C than at 20 C. Unfortunately leakage around the ultraviolet sterilizing unit resulted in mass mortality of the phyllosomes raised at 25 C.

Effect of Food

Preliminary feeding studies indicate that food has a significant effect on survival and molting frequency of the phyllosomes (Table 3). Phyllosomes are able to manipulate and feed on food items of assorted size and motility. Certain foods, *Tubifex*, *Mytilus* gonad, and *Lytechinus* eggs, did not give sufficient nourishment for continued growth and survival. Chaetognaths, ctenophores, and fish larvae, proved to be excellent food sources, but the difficulty in obtaining sufficient numbers precludes these as food sources in lengthy laboratory studies. Because of the ease of laboratory culture, naupliar and metanaupliar stages of *Artemia* were used as the major food. Phyllosomes did progress to Stage VI and lived for up to 114 days on *Artemia*.

DISCUSSION

These studies confirm reports from the literature of the difficulty in rearing phyllosome larvae. The methods of laboratory culture used in this study controlled potential problems of oxygen availability, temperature and salinity fluctuations, and bacterial contamination. Mass mortality of phyllosomes occured only twice during the study, once due to leakage around the ultraviolet sterilizing unit, and once due to leakage from a broken heater unit. Containers for individual larvae prevented entanglement of larvae, and larvae reared separately molted more readily than larvae reared in multiple culture.

TABLE 1. **Growth of laboratory-reared *Panulirus interruptus* phyllosome larvae at two temperatures.**

Stage	Length (mm) Mean ± std. dev.	Length (mm) Minimum	Length (mm) Maximum	Width (mm) Mean ± std. dev.	Width (mm) Minimum	Width (mm) Maximum	N
October, 1969 20 C							
I	1.44 ± 0.13	1.20	1.72	0.71 ± 0.06	0.60	0.89	91
II	1.81 ± 0.14	1.60	2.20	0.83 ± 0.07	0.80	1.02	72
IIIa	2.14 ± 0.11	1.82	2.31	0.94 ± 0.07	0.80	1.06	34
IIIb	2.38 ± 0.20	2.10	2.64	1.06 ± 0.06	0.99	1.12	11
IIIc	2.64 ± 0.12	2.38	2.90	1.16 ± 0.10	0.99	1.32	16
April, 1970 25 C							
II	1.72 ± 0.16	1.52	2.08	0.90 ± 0.11	0.67	1.02	9
IIIa	2.34 ± 0.17	2.05	2.71	1.05 ± 0.09	0.92	1.25	21
IIIb	2.72 ± 0.10	2.64	2.90	1.16 ± 0.03	1.12	1.19	6
IIIc	2.99 ± 0.08	2.90	3.04	1.19 ± 0.07	1.12	1.25	3
IV	3.01 ± 0.07	2.90	3.04	1.40 ± 0.28	1.12	1.39	4
June, 1970 25 C							
V	3.57 ± 0.12	3.45	3.73	1.59 ± 0.18	1.38	1.79	4
VI	3.73 ± 0.00	3.73	3.73	1.73 ± 0.00	1.73	1.73	1

TABLE 2. **Effect of Season and Temperature on Molting Frequency**

		October, 1969 20 C	October, 1969 25 C	April, 1970 25 C	June, 1970 25 C	All batches at 25 C*
Total days to molt 1 (Stage II)	N	13.12 ± 2.89 9–29 days 538 100%	11.34 ± 1.60 9–19 days 153 100%	8.55 ± 3.51 7–28 days 467 100%	7.85 ± 0.91 7–14 days 259 100%	8.63 ± 2.40 7–28 days 837 100%
Total days to molt 2 (Stage IIIa)	N	22.64 ± 2.85 19–34 days 146 27%	17.72 ± 1.44 16–24 days 71 46%	25.57 ± 3.68 18–35 days 184 39%	19.47 ± 2.31 13–30 days 127 49%	22.08 ± 4.51 13–35 days 382 46%
Total days to molt 3 (Stage IIIb)	N	32.04 ± 4.34 25–46 days 93 17%	27.75 ± 3.11 24–33 days 8 5%	35.23 ± 6.94 24–65 days 133 28%	29.94 ± 7.27 13–45 days 123 47%	33.42 ± 7.49 13–65 days 202 24%
Total days to molt 4 (State IIIc)	N	45.21 ± 4.76 39–58 days 33 6%		39.09 ± 7.04 28–54 days 36 8%	46.38 ± 14.04 26–87 days 24 9%	46.54 ± 12.93 26–87 days 78 9%
Total days to molt 5 (Stage IIId)	N	52.75 ± 4.11 49–58 days 4 .7%		42.17 ± 3.35 35–47 days 13 3%	52.33 ± 11.92 42–74 days 23 9%	54.16 ± 11.27 35–74 days 44 5%
Total days to molt 6 (Stage IV)	N			44.43 ± 8.32 37–58 days 7 1%	61.50 ± 6.27 49–74 days 20 8%	61.67 ± 10.71 37–77 days 43 5%
Total days to molt 7 (Stage V)	N			49.50 ± 3.54 47–58 days 2 .4%	71.22 ± 10.08 56–94 days 12 5%	70.73 ± 11.30 47–94 days 34 4%
Total days to molt 8 (Stage VI)	N			60.00 ± 0.00 60 days 1 .2%	85.33 ± 10.26 74–94 days 3 1%	76.00 ± 12.65 60–94 days 6 1%
Maximum days lived		77	37	77	104	114

* All batches at 25 C includes phyllosomes from October, April, June, and July batches.

TABLE 3. Effect of Food Type on Survival and Molting
(Number and Percent of Phyllosomes Entering Into Stage)

Stage/Type of food	*Artemia* nauplii	*Tubifex*	*Mytilus* gonad	*Artemia* nauplii	*Artemia* metanauplii	*Lytechinus* eggs	Ctenophores Chaetognaths	Fish larvae
I	80 100%	80 100%	80 100%					
II	28 35%	2 3%	0 0%	64 100%	64 100%	64 100%	136 100%	
IIIa	3 4%	0 0%	--- -----	26 41%	38 60%	1 2%	81 60%	54 100%
IIIb	0 0%	--- -----	--- -----	18 28%	22 35%	0 0%	42 31%	36 67%
IIIc	--- -----	--- -----	--- -----	7 11%	5 8%	--- -----	13 10%	15 28%
IIId	--- -----	--- -----	--- -----	5 8%	4 6%	--- -----	4 3%	8 15%
IV	--- -----	--- -----	--- -----	2 3%	0 0%	--- -----	4 3%	1 2%
V	--- -----	--- -----	--- -----	1 1%	--- -----	--- -----	4 3%	1 2%
Maximum days lived	35	24	18	49*	37	22	49*	21*

* Experiment terminated due to unavailability of food.

Phyllosome larvae died gradually, indicating that nutritional factors were the likely cause of death. The major problem in rearing phyllosomes is still to find an adequate food source, especially for the larger phyllosomes, which is easily reared or maintained in the laboratory. It may even be necessary to develop an artificial food to use in rearing studies.

If one examines the molting frequencies (Table 2) and selects the shortest frequencies, one can eliminate Stage IIIb and IIId as laboratory artifacts. Stage II can occur within 7 days after the larvae are shed by the berried female, Stage III in 13 days, Stage IV in 37 days, Stage V in 47 days, and Stage VI in 60 days. The maximum number of days among the stages is 24, and the average is 12 days. If one assumes that in the remaining 5 stages (Stages VII to XI) development averages 50% longer, then it would take a minimum of 5 months for the phyllosomes to develop completely from Stage I to XI. The prospects of successful laboratory rearing of *P. interruptus* through their larval history are not good unless and until a suitable food source is found.

Another possible means of enhancing the fishery of *P. interruptus* is through augmentation of the puerulus and juvenile stages. A potential method for increasing survival of the spiny lobster is to collect large numbers of puerulus larvae and/or young juveniles, rear them through the early juvenile stages in enclosed areas under elevated temperature conditions to increase growth rates, and subsequently stock them as small or medium sized, thus reducing mortality due to predation during the initial phase of benthic life in nature. Feasibility studies on this approach are currently in progress at San Diego State College.

ACKNOWLEDGMENTS

Mrs. Joan Mitchell is responsible for the design of the laboratory culturing equipment. I wish to thank Joan Mitchell, Michael Needham, and Lynn Siri for their help in the laboratory maintenance of the phyllosomes.

REFERENCES

Greve, W. 1968. The "planktonkreisel," a new device for culturing zooplankton. Mar. Biol. 1(3): 201–203.

Johnson, Martin W. 1956. The larval development of the California spiny lobster, *Panulirus interruptus* (Randall), with notes on *Panulirus gracilis*. Proc. Calif. Acad. Sci., Ser. 4, 26(1): 1–19.

Modin, John C. and Keith W. Cox. 1967. Post-embryonic development of laboratory reared ocean shrimp, *Panadalus jordani* Rathbun. Crustaceana 13: 197–219.

Robertson, Philip B. 1968. The complete larval development of the sand lobster, *Scyllarus americanus* (Smith), (Decapoda, Scyllaridae) in the laboratory, with notes on larvae from the plankton. Bull. Mar. Sci. 18(2): 294–342.

Calif. Fish and Game 58(2): 116–120. 1972.

SOUTHERN CALIFORNIA PACIFIC MACKEREL FISHERY AND AGE COMPOSITION OF COMMERCIAL LANDINGS DURING THE 1968–69 AND 1969–70 SEASONS[1]

ERIC H. KNAGGS
Marine Resources Region
California Department of Fish and Game

The southern California commercial catch of Pacific mackerel was approximately 3.3 and 1.8 million lb. during the 1968–69 and 1969–70 seasons. These landing figures represent the second and third lowest on record since the beginning of a substantial fishery in 1928.

The fishery during both seasons was dominated by the 1968 year-class in terms of both numbers and pounds. Although the strength of this 1968 year-class was a slight improvement over the past six year-classes, no significant replenishment of the already low spawning biomass can be expected.

Age composition of the catch for the last 6 months of the 1969–70 season was not calculated due to a lack of samples. Only 19.3% of the catch was landed during this period.

INTRODUCTION

Pacific mackerel, *Scomber japonicus* Houttuyn, commercial landings during the period May 1 through April 30 of the 1968–69 and 1969–70 seasons approximated 3.3 and 1.8 million lb. respectively. These are the second and third lowest landings figures since large scale canning operations started in 1928. Of the 1.8 million lb. of Pacific mackerel landed during the 1969–70 season, 80.7% of the catch was landed May through October (Table 1). Starting in late October, the southern California canners ceased to take jack mackerel, *Trachurus symmetricus* (Ayres), for human consumption due to above tolerance levels of DDT and its metabolites found in these fish. This action equally affected Pacific mackerel landings since a large amount (69.7%) was taken in mixed catches with jack mackerel during the first 6 months of the season.

TABLE 1. **Southern California Pacific Mackerel Landings in Pounds**

Month	Season 1968–69	Season 1969–70	Month	Season 1968–69	Season 1969–70
May	327,082	305,391	November	863,388	248,066
June	57,286	350,454	December	634,291	79,729
July	96,506	166,420	January	228,549	6,062
August	64,963	266,855	February	37,316	8,201
September	159,921	262,959	March	192,148	610
October	194,607	86,808	April	132,499	1,571
			Totals	3,288,556	1,783,126

[1] This study was conducted in cooperation with the Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, under Public Law 88-309, Project 6-3-R. Accepted for publication December 1971.

THE FISHERY

Cannery prices remained the same for Pacific mackerel throughout both seasons at $75 a ton. The San Pedro fresh fish market prices paid to the fishermen fluctuated between $75 and $300 a ton for round haul net caught fish, while those fish caught by other methods ranged between $100 and $400 a ton.

No Pacific mackerel were taken north of Point Conception. Most of the 1968–69 catch was taken in waters off Santa Catalina and San Clemente islands (Figure 1), while in 1969–70 (Figure 2) Santa Catalina Island, San Clemente Island, and inshore areas near San Pedro produced 63.7% of the catch (Table 2).

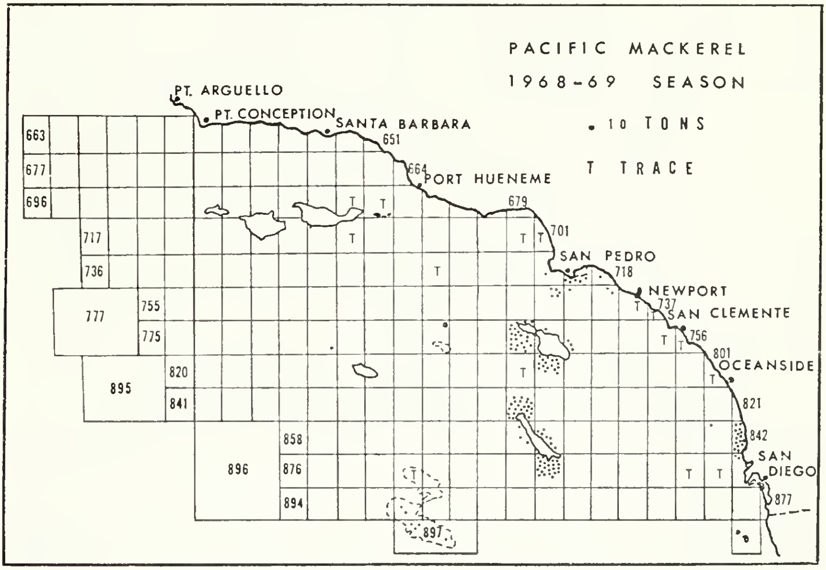

FIGURE 1. Pacific mackerel catch origins 1968–69 season.

AGE COMPOSITION

Samples were collected only at San Pedro where 99.3% (1968–69) and 99.7% (1969–70) of the fish by weight were landed. Sampling was restricted further since samples were taken only from San Pedro wetfish fleet boats which landed 89.0% and 86.9% of the southern California catch.

Age composition data for both seasons are based on 2,745 and 498 pairs of otoliths respectively. Methods used in sampling the commercial catch and estimating numbers of fish and pounds landed (Table 3) are the same as those used during the 1966–67 and 1967–68 seasons (Parrish and Knaggs, 1972).

The fishery for both seasons was completely dominated by the 1968 year-class both in numbers and pounds of fish landed. There has been six poor year-classes in a row (1962 to 1967), and none of these can be expected to contribute significant landings (Tables 4 and 5). The 1968 year-class is a slight improvement over these poor year-classes; however, this does not mean that the already low spawning biomass will be

replenished to any great extent. This, in fact, was revealed in the 1969–70 season when only 1.4 million lb. of Pacific mackerel were caught during the months when there were no catch limitations on the fishery.

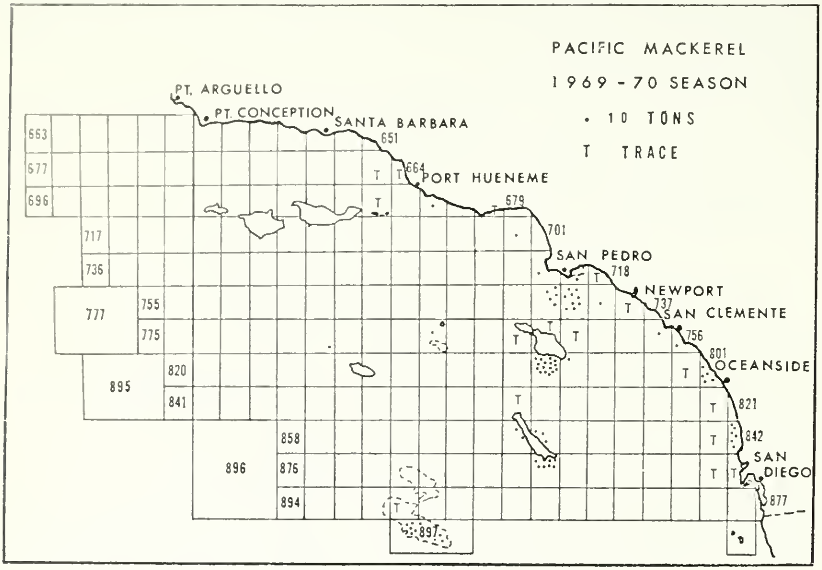

FIGURE 2. Pacific mackerel catch origins 1969–70 season.

TABLE 2. **Pacific Mackerel Landings by General Fishing Areas**

General area	1968–69 Season		1969–70 Season	
	Thousands of pounds	Percent	Thousands of pounds	Percent
Central California				
Monterey	--	--	--	--
Point Sur	--	--	--	--
Piedras Blancas	--	--	--	--
Southern California				
Santa Barbara City	--	--	1	0.1
Port Hueneme	T	T	43	3.1
Northern Channel Islands	9	0.3	4	0.3
San Pedro	316	10.5	323	23.0
Oceanside	8	0.3	135	9.6
Santa Catalina Island	863	28.7	312	22.2
Santa Barbara Island	223	7.4	15	1.1
San Nicolas Island	--	--	--	--
San Diego	386	12.8	134	9.5
San Clemente Island	1,080	35.9	259	18.4
Tanner and Cortes banks	121	4.0	178	12.7
Mexico	--	--	--	--
Totals	3,006	99.9	1,404	100.0
Pounds of unknown origin not included above	283	--	379	--
Total season's catch	3,289	--	1,783	--

TABLE 3. Age and Year-Class Composition of the Pacific Mackerel Catch in Southern California During the 1968–69 and 1969–70 Seasons

	Numbers and pounds of fish in thousands by age							
	0	I	II	III	IV	V	VI+	Totals
1968–69 Season								
Year-class	1968	1967	1966	1965	1964	1963	--	
Thousands of fish	6,313	489	182	318	77	72	109	7,559
Percent	83.5	6.5	2.4	4.2	1.0	1.0	1.4	100.0
Thousands of pounds	2,018	294	153	385	101	114	233	3,289
Percent	61.3	8.9	4.6	11.7	3.1	3.4	7.0	100.0
1969–70 Season*								
Year-class	1969	1968	1967	1966	1965	1964	--	
Thousands of fish	8	1,541	274	43	49	47	8	1,970
Percent	0.4	78.2	13.9	2.2	2.5	2.4	0.4	100.0
Thousands of pounds	2	989	239	48	70	76	15	1,439
Percent	0.1	68.7	16.6	3.3	4.9	5.3	1.1	100.0

* No estimates for last 6 months of season due to lack of samples.

TABLE 4. Number of Pacific Mackerel Landed by Age-Group for Each Year-Class From the 1950–51 Through 1969–70 Seasons in Thousands *

Year-class	Age group						
	0	I	II	III	IV	V	Totals
1950	6	1,583	521	583	71	15	2,779
1951	769	46	475	208	204	62	1,764
1952	86	676	3,893	6,021	3,641	2,302	16,619
1953	12,237	40,036	21,156	14,641	8,160	1,125	97,355
1954	564	3,562	14,976	11,332	3,493	419	34,346
1955	4,237	49,429	30,487	10,865	1,283	415	96,716
1956	21	6,228	5,915	1,050	2,008	205	15,427
1957	1,386	1,277	4,211	7,681	1,958	342	16,855
1958	16,464	56,795	19,889	9,315	3,326	704	106,493
1959	1,547	17,680	13,066	8,650	5,190	982	47,115
1960	2,498	25,621	11,987	8,505	7,634	2,648	58,893
1961	17,997	26,006	14,642	5,762	1,686	634	66,727
1962	52	2,523	3,053	519	236	32	6,415
1963	44	3,954	234	279	59	72	4,642
1964	79	386	363	101	77	†47	1,053
1965	3,990	1,881	95	318	†49	--	6,333
1966	663	136	182	†43	--	--	1,024
1967	2,866	489	†274	--	--	--	3,629
1968	6,313	†1,541	--	--	--	--	7,854
1969	†8	--	--	--	--	--	8

* For data prior to the 1950 year-class see Calif. Fish Game (46) 2:187.
† No estimates for the last six months due to lack of samples.

TABLE 5. **Pounds of Pacific Mackerel Landed by Age-Group for Each Year-Class From the 1950–51 Through the 1969–70 Seasons in Thousands ***

Year-class	Age group 0	I	II	III	IV	V	Totals
1950	1	802	471	687	90	24	2,078
1951	252	34	483	234	244	91	1,341
1952	33	463	3,063	6,034	4,394	3,112	17,099
1953	4,358	23,175	16,990	14,973	101,97	1,358	71,051
1954	94	1,964	11,722	12,294	3,854	674	30,602
1955	1,270	25,940	24,552	9,769	1,796	639	63,966
1956	5	4,222	4,283	1,302	2,751	287	12,850
1957	466	664	4,104	9,012	2,529	522	17,297
1958	4,454	32,638	18,010	10,407	4,499	1,104	71,112
1959	505	7,661	11,451	10,386	6,985	1,626	38,617
1960	562	13,732	11,549	9,974	10,659	2,702	49,178
1961	5,659	18,206	14,327	6,939	2,217	1,181	48,529
1962	32	1,660	2,893	573	337	54	5,495
1963	19	2,622	198	344	79	114	3,376
1964	30	166	336	119	101	†76	828
1965	960	877	87	385	†70	--	2,379
1966	217	82	153	†48	--	--	500
1967	801	294	†239	--	--	--	1,334
1968	2,018	†989	--	--	--	--	3,007
1969	†2	--	--	--	--	--	2

* For data prior to the 1950 year-class see Calif. Fish Game (46) 2:188.
† No estimates for the last six months due to lack of samples.

CONCLUSIONS

Since the 1962 year-class there has been six and probably seven poor year-classes in a row. This represents the longest period of poor year-classes in fisheries' history. Subsequently the spawning biomass has not been replenished and is now at a very low level.

The poor year-classes and low landings indicate that the present Pacific mackerel fishery may result in a long term loss of this once large resource unless there is a complete moratorium enacted on taking these fish. (A moratorium went into effect on November 23, 1970 and no loads of fish may contain more than 18% by weight of Pacific mackerel taken incidentally to other fishing operations.)

REFERENCES

Parrish, Richard H., and Eric H. Knaggs. 1972. The southern California Pacific mackerel fishery and age composition of the catch for the 1964–65 through 1967–68 seasons. Calif. Fish Game 58(1) : 13–21.

Calif. Fish and Game 58(2): 121–126. 1972

AGE AND LENGTH COMPOSITION OF NORTHERN ANCHOVIES, *ENGRAULIS MORDAX*, IN THE CALIFORNIA ANCHOVY REDUCTION FISHERY FOR THE 1969–70 SEASON[1]

JEROME D. SPRATT
Marine Resources Region
California Department of Fish and Game

Anchovy landings totaled 83,472 tons during the 1969–70 season. Sampling revealed that the catch was dominated by age groups 0, I, and II in southern California, and age groups I and II in central California.

INTRODUCTION

This is the third in a continuing series of reports on the age and length composition of anchovies landed for reduction in California. The data presented are the results of sampling anchovy reduction landings during the 1969–70 season (September 15, 1969—May 15, 1970 in southern California and August 1, 1969—May 15, 1970 in central California). Methods of sampling and age determination are the same as used by Collins (1971).

The two fishing areas, central and southern California (Messersmith, 1969), produced landings of 83,472 tons with 97.6% being caught in southern California and 2.4% in central California (Table 1). Catch estimates for southern California are based on only San Pedro landings, which provided 87% of the southern California landings. The remaining 13% was landed at Port Hueneme. A total of 478 samples was taken and 6,498 individual fish were processed.

Catch estimates for central California were based on Moss Landing (Monterey Bay) landings. A total of 58 samples was taken and 555 individual fish were processed.

TABLE 1. **Tons of Anchovies Landed by Area During the 1969–70 Season**

	Tons	Percent
Southern California		
San Pedro	71,151	85.3
Port Hueneme	10,301	12.3
		97.6
Central California		
Moss Landing	2,020	2.4
Total	83,472	100.0

[1] Accepted for publication November 1971.

LENGTH COMPOSITION OF THE CATCH

Southern California

Anchovies sampled ranged from 74 mm SL to 166 mm SL. The mean length for all year classes, except 0's, was 2 to 9 mm SL larger than in the 1968–69 season. More anchovies were sampled in the spring of the 1969–70 season than in previous seasons. These fish caught late in the season will tend to average longer than those caught early because of growth, so sampling late in the season could account for most of the difference noted.

Fish from 105–134 mm SL comprised nearly 79% of the estimated 3.5 billion anchovies caught during the 1969–70 season (Table 2). This is slightly less than the 1968–69 season when Collins (1971) reported 85% of the anchovies were in the 105–134 mm SL length group.

TABLE 2. **Estimated Number of Anchovies by Length Class Landed at San Pedro During the 1969–70 Anchovy Season**

Length class mm SL	Estimated number	Standard deviation	Estimated percent of landings
75– 84	21,469,809	11,941,556	.60
85– 94	61,382,675	10,899,271	1.72
95–104	295,283,035	11,308,845	8.28
105–114	670,070,846	27,602,981	18.80
115–124	1,109,681,504	28,871,715	31.13
125–134	1,023,981,915	23,169,070	28.73
135–144	337,311,532	15,448,989	9.46
145–154	42,512,176	5,324,270	1.19
155–164	2,306,985	1,303,091	.07
165–174	605,964	544,000	.02
Total	3,564,606,441	--	100.00

Central California

Anchovies sampled from central California ranged in length from 97 mm SL to 168 mm SL. Anchovies 115–144 mm SL comprised 82% of the estimated 61 million caught during the 1969–70 season (Table 3). This length group accounted for nearly 77% of the landings during the 1968–69 season. No differences were apparent when mean-lengths-at-age were compared with previous seasons.

TABLE 3. **Estimated Number of Anchovies by Length Class Landed in Central California During the 1969–70 Anchovy Season**

Length class mm SL	Estimated number	Standard deviation	Percent of landings
95–104	190,133	150,312	.31
105–114	2,074,464	633,506	3.36
115–124	10,719,844	2,349,463	17.36
125–134	18,812,067	2,411,515	30.47
135–144	21,363,436	1,689,970	34.60
145–154	7,667,307	1,337,390	12.42
155–164	772,438	731,303	1.25
165–174	145,871	105,250	.23
Total	61,745,560	--	100.00

TABLE 4. **Estimated Number of Anchovies by Year Class Landed During the 1969–70 San Pedro Reduction Season**

Year class (Age)	1969 (0)	1968 (I)	1967 (II)	1966 (III)	1965 (IV)	1964 (V)	1963 (VI)	Total
Number	961,554,781	991,943,964	1,255,894,842	294,881,433	54,606,255	4,164,044	1,561,122	3,564,606,441
Standard deviation	38,738,224	26,966,227	24,395,684	14,301,874	6,297,811	1,623,180	849,563	
Percent of landings	26.98	27.83	35.23	8.27	1.53	.12	.04	100.0

TABLE 5. **Estimated Weight of Year Classes Landed During the 1969–70 San Pedro Anchovy Reduction Season**

Year class (Age)	1969 (0)	1968 (I)	1967 (II)	1966 (III)	1965 (IV)	1964 (V)	1963 (VI)	Total
Pounds	27,054,520	38,252,684	57,340,207	15,940,259	3,338,400	266,918	109,853	142,302,841
Standard deviation	928,189	1,029,955	1,126,056	784,591	392,034	106,971	60,744	
Percent of landings	19.01	26.88	40.29	11.20	2.35	0.19	0.08	100.0

Comparison of mean-length-at-age data from central and southern California shows the mean length of a given age group to be 5–9 mm SL larger in central California. No reason is apparent, but it does agree with previous seasons.

AGE COMPOSITION OF THE CATCH

Otoliths were taken from samples for age determination. Age and year class were assigned using the method described by Collins and Spratt (1969).

Southern California

The year class composition of the 1968–69 season catch was dominated by age I fish, comprising nearly 46% by number and 42% by weight (Collins, 1971). This large year class again dominated the 1969–70 season catch as age II fish, accounting for 35% by number and 40% by weight of catch (Tables 4 and 5). Age group 0, I, and II comprised 90% of 1969–70 catch.

Central California

Anchovies in age groups I, II, and III comprised 93% of the catch both in number and weight (Tables 6 and 7). Age group II fish were dominant in both number and weight, accounting for 46% and 48% respectively of the catch. These figures are higher than the 1968–69 season when age groups I, II, and III totaled 71% of the catch by number and 69% by weight (Collins, 1971).

SEX AND BIOMASS RATIO

During the 1969–70 southern California anchovy reduction season, 81,452 tons were landed, more than three times 1968–69 season landings. Data indicated a female to male numerical ratio of 1.14:1 and a weight ratio of 1.27:1 (Table 8). The difference between numerical and weight ratios is caused by a tendency for females to be larger than males for any given age (Collins and Spratt, 1969). Collins (1971) calculated numerical and weight ratios of 1.4:1 and 1.5:1 respectively for the 1968–69 San Pedro reduction season. Clark and Phillips (1952) estimated female to male numerical ratios of 1.2:1 for southern California.

The 1969–70 central California reduction season produced fewer landings than the two previous seasons. Samples indicated female to male numerical ratios of .63:1 and weight ratios of .70:1 (Table 8). These figures differ widely from previous estimates. Collins and Spratt (1969) estimated numerical and weight ratios of 1.3:1 and 1.4:1 respectively for the 1967–68 central California season which agrees with estimates of Clark and Phillips (1952) and MacGregor (1968).

ACKNOWLEDGMENTS

I wish to express my sincere thanks to all the people who participated in collecting and analyzing the data. Paul Zellmer and James Hardwick collected samples in southern and central California respectively. The otoliths were read by Robson A. Collins, David A. Hoopaugh and Stephen J. Crooke of the Department. Computer operations were handled by Catherine Berude. Gayle Jones and Micaela Wolfe typed the manuscript for publication.

TABLE 6. Estimated Number of Anchovies by Year Class Landed During the 1969–70 Central California Reduction Season

Year class (Age)	1969 (0)	1968 (I)	1967 (II)	1966 (III)	1965 (IV)	Total
Number	1,601,403	19,034,238	28,201,820	10,571,283	2,336,816	61,745,560
Standard deviation	371,116	3,043,661	2,273,233	3,256,003	1,561,460	
Percent of landings	2.59	30.83	45.67	17.12	3.78	99.99

TABLE 7. Estimated Weight of Year Classes Landed During the 1969–70 Central California Anchovy Reduction Season

Year class (Age)	1969 (0)	1968 (1)	1967 (II)	1966 (III)	1965 (IV)	Total
Number	61,042	1,007,528	1,933,502	836,279	201,649	4,040,000
Standard deviation	13,743	148,751	139,130	268,767	149,043	
Percent of landings	1.51	24.94	47.86	20.70	4.99	100.00

TABLE 8. Sex and Biomass Ratio for the 1969–70 Anchovy Reduction Season

Sex ratio (numbers)		
	San Pedro	Central Calif.
Males		
Number	1,634,525,892	37,752,705
Percent	45.85	61.14
Females		
Number	1,866,726,373	23,796,217
Percent	52.37	38.54
Unknown		
Number	63,354,159	196,637
Percent	1.78	.32
Females:Males	1.14:1	.63:1
Biomass ratio (weight)		
Males		
Pounds	62,024,173	2,365,011
Percent	43.57	58.54
Females		
Pounds	78,837,175	1,664,995
Percent	55.40	41.21
Unknown		
Pounds	1,441,511	9,994
Percent	1.01	.24
Females:Males	1.27:1	.70:1

REFERENCES

Clark, Frances N., and Julius B. Phillips. 1952. The northern anchovy (*Engraulis mordax mordax*) in the California fishery. Calif. Fish Game 38(2):189–207.

Collins, Robson A. 1969. Size and age composition of northern anchovies (*Engraulis mordax*) in the California anchovy reduction fishery for the 1965–66, 1966–67 and 1967–68 seasons: 56–74. *In* The northern anchovy (*Engraulis mordax*) and its fishery 1965–68. Calif. Dep. Fish and Game, Fish. Bull. (147):1–102.

Collins, Robson A. 1971. Size and age composition of northern anchovies, (*Engraulis mordax*) in the California reduction and canning fisheries, 1968–69 season. Calif. Fish Game 57(4): 283–289.

Collins, Robson A., and Jerome D. Spratt. 1969. Age determination of northern anchovies, *Engraulis mordax*, from otoliths:39–55. *In* The northern anchovy (*Engraulis mordax*) and its fishery 1965–68. Calif. Dep. Fish and Game, Fish. Bull. (147):1–102.

MacGregor, John S. 1968. Fecundity of the northern anchovy, *Engraulis mordax* Girard. Calif. Fish Game 54(4): 281–288.

Messersmith, James D., and staff. 1969. The northern anchovy (*Engraulis mordax*) and its fishery 1965–68. Calif. Dep. Fish and Game, Fish. Bull. (147):1–102.

California. Fish and Game 58(2): 127–132. 1972.

ACUTE TOXICITY OF FOUR ORGANOCHLORINE INSECTICIDES[1] TO TWO SPECIES OF SURF PERCH

RUSSELL D. EARNEST[2]
and
PETE E. BENVILLE, JR.
Fish-Pesticide Research Laboratory
Bureau of Sport Fisheries and Wildlife
United States Department of the Interior
Columbia, Missouri

The acute toxicities of endrin, DDT, aldrin and dieldrin to shiner perch (*Cymatogaster aggregata*) and dwarf perch (*Micrometrus minimus*) were determined by static and intermittent-flow bioassays. Toxicity was measured as the Median Lethal Concentrations (TL_{50}) for 96-hr exposures. TL_{50} values were lower in intermittent-flow bioassays than in static bioassays. We also compared residue concentrations in surviving and dead fish from the intermittent-flow bioassays. Residue concentrations in fish that died during tests were higher than those of fish that survived. However, the range of concentrations in dead and surviving fish overlapped.

INTRODUCTION

San Francisco Bay represents an ecological area where large amounts of pesticides enter from drainage systems. Measurable concentrations of aldrin, dieldrin, endrin and DDT have been detected in the San Francisco Bay water (Earnest, unpublished). Increasing attention is being devoted to effects of pesticides on estuarine fishes. Eisler (1970) revealed vast differences in the toxicities of 12 insecticides to seven species of estuarine teleosts in static bioassays.

Because little is known concerning the effects of organochlorine insecticides on Pacific Coast estuarine fishes, we determined the acute toxicities of four organochlorine insecticides to shiner perch, *Cymatogaster aggregata*, and dwarf perch, *Micrometrus minimus*. The results obtained from static and intermittent-flow bioassay systems utilizing estuarine water were compared and insecticide concentrations in live and dead fish were determined for correlating whole body residue concentrations with mortality.

METHODS

The surfperch we used were collected by otter trawl in San Francisco Bay near Tiburon, California. They were acclimated in glass aquaria containing filtered Bay water for at least 1 week before testing and were fed frozen brine shrimp daily. The fishes ranged from 48 to 104 mm TL and weighed 1.2 to 11.0 g.

[1] Accepted for publication November 1971.
[2] Bureau of Sport Fisheries and Wildlife, Division of River Basin Studies, Sacramento, California 95825.

Because of the oxygen demand of turbid, saline water (Brown and Clark, 1968), we had difficulty maintaining acceptable dissolved oxygen levels for 96 hr in static bioassays. Therefore, we used only two or three fish per concentration to avoid driving the toxicant from solution by aeration. Originally, we had hoped to compare toxicity data obtained by static and intermittent-flow bioassays. But because of the small numbers of fish used in the static tests, these data were used primarily for establishing insecticide concentrations to be used in the intermittent-flow bioassays. Limited holding space and small numbers of fish of the same size prevented us from running replicates. Satisfactory levels of dissolved oxygen were easily maintained in intermittent-flow bioassays since the water is replenished regularly. Therefore, we exposed five fish at each concentration.

All bioassays were run in 65-liter glass aquaria. Test water was delivered through a sand filter, but no attempt was made to maintain a specific turbidity or salinity although these factors can effect pesticide concentrations (Earnest and Benville, 1970). In the intermittent-flow bioassays, turbidities and salinities were determined with a Hach 2100 nephelometer and a Kahlsico salinity hydrometer, respectively. Turbidity and salinity were determined only on the first day in the static tests. Temperatures of static bioassays were maintained by waterbath at 13 C (± 1), but intermittent-flow water temperatures were not controlled and fluctuated from 14 to 18 C. Test fish were not fed for 24 hr preceding, or during, a bioassay.

Insecticides used in this study were supplied by City Chemical Corporation, New York. All insecticides were technical grade and consisted of aldrin (1,2,3,4,10,10-hexachloro-4,4,4a,5,8,8a-hexahydro-1,4-endo-exo-5,8-dimethanonapthalene), dieldrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-exo-5,8-dimethanonapthalene), endrin (1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4-endo-endo-5,8-dimethanonapthalene) and DDT (1,1,1-trichloro-2,2-bis (p-chlorophenyl)ethane(*p,p'* isomer).

The proportional diluter we used for the intermittent-flow tests was described by Mount and Brungs (1967). All intermittent-flow stock solutions had ethanol as the solvent. Stock solutions for static tests were prepared by dissolving the insecticide in acetone. Serial concentrations, of the stock solution, were pipetted into the aquaria at least 2 hr after fish had been introduced. The same amount of acetone used in the highest concentration was added to the control. Mortality was recorded daily, but only the 96-hr results are reported. The TL_{50} values (tolerance limits for 50% of the test animals) for static tests were determined graphically with logarithmic-probability paper. The diluter data were converted to logs and probits and a linear regression equation calculated according to a modification of Litchfield and Wilcoxin's (1949) method.

Whole body residue concentrations were determined for fish exposed in either preliminary or definitive diluter bioassays. The analytical procedures as described by Earnest and Benville (1971) were used. Mean residue concentrations were recorded for fish that either died during, or survived the 96-hr bioassays.

RESULTS

In static bioassays, endrin was the most toxic of the four insecticides to both species of surfperch (Table 1). Because of the small number of fish exposed at each concentration, little emphasis could be placed on the static bioassay data. The TL_{50} values as determined by intermittent-flow bioassays were much lower than those for the static tests (Tables 1 and 2). For example, the static TL_{50} of DDT for shiner and dwarf perch was 7.6 and 4.6 μg/liter, but the intermittent-flow values were 0.45 and 0.26 μg/liter, respectively. As in the static tests, endrin was significantly more toxic than aldrin or dieldrin. There was no significant difference in resistance between shiner and dwarf perch in the intermittent-flow bioassays.

TABLE 1. Toxicity of Four Organochlorine Insecticides to Shiner and Dwarf Perch at 13 C in Static Bioassays

Species	Insecticide	Turbidity (JTU)	Salinity (⁰/₀₀)	96-hr TL_{50} (μg/liter)
Shiner perch	Endrin	5.0	26.0	0.8
	Dieldrin	28.0	15.0	3.7
	Aldrin	5.0	28.0	7.4
	DDT	0.5	26.0	7.6
Dwarf perch	Endrin	13.0	18.0	0.6
	DDT	1.0	28.0	4.6
	Dieldrin	0.5	29.0	5.0
	Aldrin	18.0	16.0	18.0

Because of the small number of fish, insecticide concentrations and their range are presented for all fish that were dead, or all fish that survived at the termination of the bioassay (Table 3). Residues of endrin found in the tissues of dead endrin-exposed fish were lower than those of DDT in dead DDT-exposed fish. In three of four samples, less aldrin than dieldrin was found in the tissue of the aldrin-exposed fish. Thus, a considerable amount of aldrin appears to have been metabolized to dieldrin by the time the fish had died or the bioassay was terminated. Any effects that the aldrin-dieldrin metabolic relationship might have had on toxicity values is unknown. Residue levels in some fish that died during certain experiments were lower than residue levels in fish that survived at 96 hr. This same relationship was observed by Woodwell, Wurster, and Isaacson (1967).

TABLE 2. Toxicity of Four Organochlorine Insecticides to Shiner and Dwarf Perch in Intermittent-flow Bioassays

Species	Insecticide	Turbidity (JTU) mean (range)	Salinity (⁰/₀₀) mean (range)	96-hr TL_{50} (95% C.I.) (μg/liter)
Shiner perch	Endrin	7 (2–8)	28 (27–28)	0.12 (0.06–0.25)
	DDT	12 (9–16)	18 (13–23)	0.45 (0.21–0.94)
	Dieldrin	6 (5–8)	28 (26–28)	1.50 (0.73–3.20)
	Aldrin	7 (5–10)	25 (25–26)	2.26 (1.08–4.74)
Dwarf perch	Endrin	2 (2–3)	28 (27–28)	0.13 (0.06–0.27)
	DDT	4 (3–5)	27 (26–28)	0.26 (0.13–0.52)
	Aldrin	7 (2–8)	28 (27–28)	2.03 (1.00–4.20)
	Dieldrin	24 (10–28)	12 (10–21)	2.44 (1.16–5.11)

TABLE 3. **Residue Concentrations (mg/kg) of Four Organochlorine Insecticides in Dead and Surviving Shiner and Dwarf Perch After 96 Hr of Exposure in Intermittent-flow Bioassays**

Insecticide	Shiner perch			Dwarf perch		
	Dead	Alive	Control	Dead	Alive	Control
	mean (range)	mean (range)		mean (range)	mean (range)	
Endrin	0.13 (0.02–0.27)	0.07 (0.03–0.09)	ND*	0.11 (0.08–0.15)	0.04 (0.02–0.06)	ND
DDT	0.55 (0.41–0.65)	0.35 (0.24–0.48)	.040	1.00 (0.48–2.00)	No sample	.028
Dieldrin	2.33 (1.68–3.07)	1.34 (0.67–2.24)	.027	1.26 (0.86–1.70)	0.44 (0.22–0.65)	.008
Aldrin	1.00 (0.23–3.40)	0.42 (0.12–0.92)	ND	0.38 (0.22–0.54)	0.20 (0.04–0.36)	ND
Dieldrin†	0.78 (0.19–1.02)	0.58 (0.24–1.00)		1.00 (0.77–1.24)	0.34 (0.13–0.59)	

* Less than 0.001 considered not detectable.
† Dieldrin concentrations in fish exposed to aldrin.

DISCUSSION

The tremendous quantity of pesticides entering estuarine environments (Risebrough, 1968) makes it mandatory that we have some knowledge of the acute effects of these compounds on wildlife. We found that less than 3 μg/liter of endrin, DDT, aldrin, and dieldrin, under the described experimental conditions, are lethal to shiner and dwarf perch. Present levels of DDT in San Francisco Bay average approximately 0.4 μg/liter. Aldrin, dieldrin and endrin occur less frequently and at lower concentrations than DDT (Earnest, unpublished).

The temperature difference in the intermittent-flow tests could have influenced the toxicity levels (Macek, et al. 1969). Eisler (1970) found that in static bioassays, temperature influenced the toxicity of some organophosphate and organochlorine insecticides to a species of estuarine fish. He also found that different salinities had little effect on the toxicity of DDT or endrin to the species of fish tested. Katz and Chadwick (1961) also reported that different salinity levels had little effect on the toxicity of endrin to stickleback, but temperature variation greatly affected the toxicity of endrin to bluegills.

The results we obtained with a proportional diluter, for the size of fish we tested, are more meaningful than those in static tests. Under static conditions, oxygen and waste products are limiting factors (Lincer, Solon, and Nair, 1970). Also, pesticides may be sorbed by the organisms, glass and silt, resulting in higher TL_{50} values (unpublished data, Fish-Pesticide Research Laboratory, Columbia, Missouri.

Data on whole body residue concentrations in organisms have certain limitations since the length of exposure and concentration of contaminants are unknown (Butler, 1966). However, our results do suggest a correlation between residue concentration and mortality after relatively brief exposures, even though the effect of the residues at specific sites is unknown. Typically, when using estuarine water, we experienced variations in salinity and turbidity in our test solutions. This may have contributed to some variations in our bioassay results. However, during the winter and spring runoff when turbidities are high, salinities are low, and Bay fish are in their poorest condition, an estuary, such as San Francisco Bay, is probably receiving its heaviest pesticide load (Earnest and Benville, 1970). Bioassays must be run under these conditions to best simulate the factors that are affecting estuarine organisms in their natural environment.

ACKNOWLEDGMENTS

This study would not have been possible without the technical assistance of Mrs. Margie Gepner and Mrs. Vivian Cartwright.

REFERENCES

American Public Health Association. 1965. Standard methods for the examination of water and wastewater including bottom sediments and sludges, 12th Ed. A.P.H.A. Inc., New York, N 769 p.

Benville, P. E., Jr., and R. D. Earnest. 1970. Organochlorine insecticide concentrations in water; effects of salinity and turbidity. Unpublished manuscript.

Brown, C. and R. Clark. 1968. Observations on dredging and dissolved oxygen in a tidal waterway. Water Resources Res. 4(6): 1381–1384.

Butler, P. A. 1966. The problem of pesticides in estuaries. p. 110–115. In: A symposium on estuarine fisheries. Amer. Fish. Soc. Spec. Publ. 3, 154 p.

Earnest, R. D. and P. E. Benville, Jr. 1971. DDT residue and lipid correlations for certain San Francisco Bay fish. Pestic. Monit. J. 5(3): 235–241.

Eisler, R. 1970. Factors affecting pesticide-induced toxicity in an estuarine fish. U.S. Bureau of Sport Fisheries and Wildlife. Technical Paper (45): 1–20.

Kaiser Engineers. 1969. San Francisco Bay Delta water quality control program. Final report to the state of California, 12 p.

Katz, M., and G. G. Chadwick. 1961. Toxicity of endrin to some Pacific Northwest fishes. Trans. Amer. Fish. Soc. 90(4): 394–397.

Lincer, J., J. Solon, and J. Nair. 1970. DDT and endrin fish toxicity under static versus dynamic bioassay conditions. Trans. Amer. Fish. Soc. 99(1): 13–19.

Litchfield, J. T., and F. Wilcoxin. 1949. A simplified method of evaluating dose-effect experiments. J. Pharmacol. Exptl. Therap. 96(2): 99–113.

Macek, K., C. Hutchinson, and O. Cope. 1969. The effects of temperature on the susceptibility of bluegills and rainbow trout to selected pesticides. Bull. Environ. Cont. Tox. 4(3): 174–183.

Mount, D., and W. Brungs. 1967. A simplified dosing apparatus for fish toxicological studies. Water Research 1: 21–29.

Risebrough, R. W. 1968. Chlorinated hydrocarbons in marine ecosystems. Unpublished manuscript.

Woodwell, G., C. Wurster and P. Isaacson. 1967. DDT residues in an East Coast estuary: A case of biological concentration of a persistent insecticide. Science 156 (3,776): 821–824.

Calif. Fish and Game 58(2): 133–140. 1972.

THE MINERAL KING DEER HERD[1]

EDWARD R. SCHNEEGAS
United States Forest Service
San Francisco
and
GEORGE W. FRANKLIN
Wildlife Management Branch
California Department of Fish and Game

A cooperative deer study was conducted by the California Department of Fish and Game and the U. S. Forest Service on the summer and winter ranges of the Mineral King herd, Tulare County, from July, 1969, to July, 1970. The key winter range was located and mapped during the 1969–70 winter by observation of marked deer.

In July and August of 1969, 48 deer were trapped in Mineral King on the summer range. Bells were placed on 43 adult does and three were also fitted with radio telemeters. Four bucks and one fawn were ear tagged.

Deer began moving to the winter range in early October when the first storm occurred. The distance traveled was from 10 to 18 miles. In 1970 the deer returned to the summer range, mostly during May. Radio monitoring of a doe showed she made the return trip from the winter to the summer range in 3 days.

INTRODUCTION

The study of the Mineral King deer herd was undertaken at this time because of the proposed recreational development of the area by Walt Disney Productions and the Forest Service.

The village and parking sites proposed for the Mineral King Recreation Development, will occupy about 35 acres in the valley floor. The total development will use approximately 60 acres. Summer homes now occupy a portion of the 35 acres in the valley floor.

The anticipated increase in public use, and the impact on the deer habitat will create changes in management and the deer hunting policy which will require better understanding and knowledge of this herd.

Hunting has been the method used in the past to adjust deer population numbers to the available forage and living space. As recreational development progresses and more and more people are present in the area, hunting may conflict with other uses of the development. When this occurs, hunting may have to be conducted only on the winter range.

The objectives of this study were to determine the specific wintering area of the Mineral King deer herd, the migration pattern and the approximate migration dates and to gather other basic information needed for management.

To achieve these objectives, plans were developed jointly by the California Department of Fish and Game, and the U.S. Forest Service, to trap and mark 50 deer on the summer range in Mineral King. These animals would then be observed during the summer, their migration to the winter range followed, and the wintering area defined by locating the belled animals.

[1] Accepted for publication January 1972

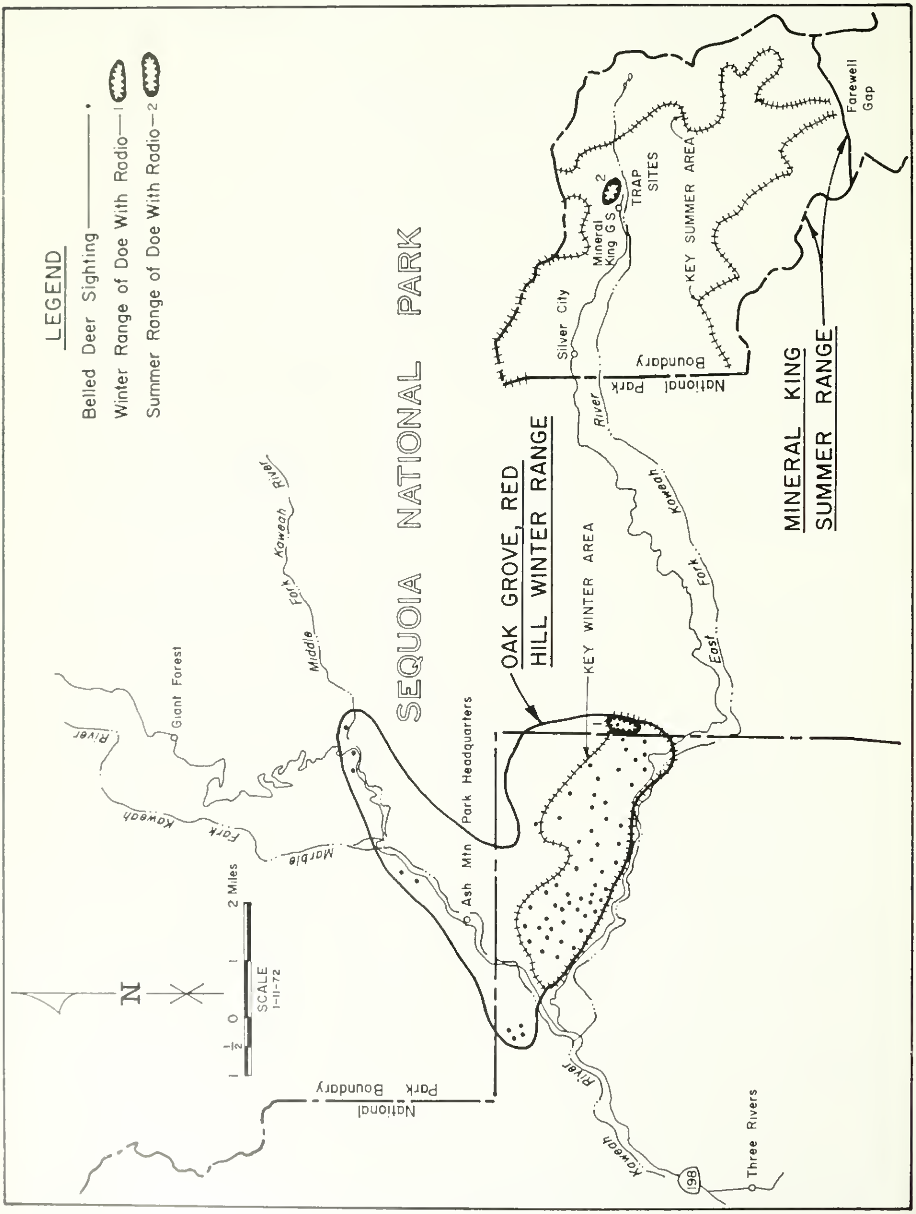

FIGURE 1. Map showing summer and winter ranges of the Mineral King Deer Herd. Drawn by K. Gonzoles.

The Mineral King deer herd occupies a range on the west slope of the Sierra Nevada in Tulare County. These California mule deer (*Odocoileus hemionus californicus*) summer in Mineral King at 6,000 to 10,000 ft and winter near Three Rivers, California, at 1,500 to 3,500 ft (Figure 1). The airline distance between the two ranges is about 10 miles; however, because of the steep, rough terrain, deer travel 10 to 18 miles. These deer are a part of the designated Kaweah River deer herd, because their range is within the Kaweah River watershed.

The deer range on lands managed by three public agencies. The summer range is administered by the Sequoia National Forest and Sequoia National Park; the winter range by the National Park and the Bureau of Land Management. Deer also range on private property during the winter.

HISTORY OF MINERAL KING

The Sequoia National Game Refuge, better known as Mineral King, is cradled between the Sequoia and Kings Canyon National Park on three sides, and the Sequoia National Forest on the southern portion, and includes 15,630 acres. It was created by the Act of July 3, 1926 (44 State 821; 16 U.S.C. 688) at the time the Sequoia National Park was enlarged, for the protection of wildlife ranging between Sequoia National Park and Mineral King. The Secretary of Agriculture may permit uses of these lands insofar as they are compatible with the purpose for which the refuge was established.

The first management of livestock occurred in 1929. A permit for 48 head of cattle was allowed from 1935 to 1946, and some pack stock grazed the meadows until 1957.

Prior to the establishment of the Sequoia National Game Refuge the area was lightly hunted. From 1926 to 1950 all hunting was prohibited.

Deer herd census and range surveys made by the Department of Fish and Game and the U.S. Forest Service in the late 1940's revealed an exceedingly high deer population, and an extremely poor browse condition, the result of over-utilization by deer.

A reduction in deer numbers by special, either-sex hunting was recommended. The first hunt was authorized by the California Fish and Game Commission and sanctioned by the Forest Service in 1950. Subsequent special hunts followed to 1967, but after that the area was open during the regular buck season with no restrictions as to the number of hunters.

The first hunt in 1950, with 960 permits sold, produced 677 deer (Table 1). The 10 intermittent hunts that followed during the next 20 years provided 1,948 deer to the hunters.

METHODS

Trapping and Tagging

During the period July 4 to August 14, 1969, 18 Clover traps were operated by the Department of Fish and Game and U.S. Forest Service. Because of the steep terrain, the traps were confined to the narrow valley floor and slightly below the area that appeared to be the major fawning zone.

TABLE 1. **Deer Harvest in Mineral King**

Year	Number permits	Male	Female	Unclassified	Total harvest
1950	966	394	283	0	677
1955	500	222	161	0	383
1957	375	126	129	1	256
1958	300	82	88	1	171
1959	300	46	59	0	105
1960	200	45	30	9	84
1966	200 bucks only	68	0	0	68
1967	300 bucks only	29	0	0	29
1968	unrestricted bucks only	36	0	0	36
1969	unrestricted bucks only	33	0	0	33

Three different baits were used to attract deer: table salt, common mistletoe (*Phoradendron villosum*), and dairy supplement. Table salt was the most successful. Each trap initially received about 1 lb. of salt but with capture activity it was lost and had to be replenished. The average amount required for each trap during the 6 weeks period was 4 lb. Some use was made of the mistletoe, and when used in combination with salt attracted deer more readily. Use of the dairy supplement had to be discontinued as it was attractive to rodents, especially marmots (*Marmota flaviventris*). In their search for this bait they would trip the trigger mechanism, making the trap inoperative for the night.

Each trapped deer was marked for future recognition by a combination of ear tag with plastic streamer, and a colored collar with bell. Bells were not placed on bucks, but each was ear-tagged.

Radio Telemetry

Radio transmitters were attached by collar to three of the belled does to obtain data on movement within the summer and winter range areas.

The radio transmitters were obtained from Davidson Electronics and Electronics Unlimited. The Electronics Unlimited transmitter collars with 31.22 MHz were placed on two does on July 24 and 25, 1969. The third transmitter, Davidson Electronics with 31.34 MHz, was attached on July 24, 1969. This transmitter signal was receivable up to 15 miles direct line of sight, while the former two were limited to a 2-mile line of sight transmission.

Deer Herd Composition Surveys

On September 17 and 18, 1969, deer herd composition survey counts were made in Mineral King by the Department and the Forest Service to determine fawn production, sex ratio of the herd, and to gather comparable information of marked and unmarked deer for use in arriving at an estimate of the deer population. In order to obtain a reliable count representative of the total key area, a four-man crew was used with emphasis on an evening and early morning survey. The first count was in the evening from the valley floor, and the second the following morning at higher elevations by horseback.

RESULTS

Tagging and Trapping

Forty-eight of the authorized 50 deer were captured in a 6-weeks period on the summer range. Thirty-four of the 48 were caught during the middle 3 weeks of the period, July 4 to August 14, 1969.

Three deer died during the trapping activities. A three-point buck was killed in a trap by a large black bear (*Euarctos americanus*); an adult doe died in a trap from injury, possibly the result of bear harassment; and a doe, after release, crashed into a ledge that was screened from her view by brush.

During the first weeks of the trapping period fawns were not observed moving with the does, and apparently did not follow their mothers into the trapping area to any extent, as none were taken by trap. Only one fawn was captured, and that by hand during daylight. As the summer progressed, fawns were seen frequently along the manzanita (*Arctostaphylos* sp.) belt above the valley floor (Figure 2) and occasionally in the valley floor. An examination of 40 adult does trapped showed 32 were lactating, or 80%, indicating a high fawning rate.

FIGURE 2. View of the Mineral King summer range. Photo taken 1969.

The age class sample of the 44 females captured showed 65% were in the 4-year-and older age group. Of the four bucks caught, three, or 75% were 4 years or older; one was an old stag with the typical in-velvet antler moss.

Deer Herd Sex and Age Ratios

Deer herd sex ratio information was obtained from surveys made in the field in September, 1969. The field census data showed 12 bucks per 100 does and 47 fawns per 100 does based on 94 deer classified.

Deer Population Estimates

From the trapping and marking project it was possible to estimate deer numbers in Mineral King during the summer of 1969. Both the Lincoln Index, and *Methods for Estimating Deer Populations from Kill Data* (Dasmann, 1952) were used with the field information obtained.

The Lincoln Index requires a comparison of marked to unmarked animals. With this technique, we arrive at an estimate of 299 deer on the summer range. Bells and colored collars could have biased the count, but observers generally saw the deer before the colored collar. In some cases the bell was first heard. However, under the favorable conditions for classifying deer over most of this area, and with the use of experienced personnel, it is felt these animals would have been seen almost as soon.

In using Dasmann's method we estimated that half of the yearling bucks were legal and half of the legal bucks were taken. This left 12.5 deer in the field for each buck in the harvest. The 3-year average buck kill for 1967, 1968 and 1969 was 32 animals. This method placed the summer population at 384 deer.

After comparing the two census methods and from field observations, we estimated the deer population at approximately 350 during the summer of 1969 at Mineral King.

Fawn production indicated the deer numbers were static.

Radio Telemetry of Summer and Winter Deer Movements

The Electronics transmitter collars with 31.22 MHz attached to the two does furnished little information as contact was lost after 2 weeks on the summer range. Loss of radio reception was probably due to battery failure. The third transmitter from Davidson Electronics attached on July 24, 1969, provided a strong signal from July 24, 1969 to July 7, 1970. The activity of this doe was monitored during this 1-year period by ground and air search.

From July 24, 1969, when the radio transmitter was placed on the doe, she was observed many times on the summer range with a fawn, and at all times within a $\frac{1}{2}$-mile area of the trap site. The signal was received in Mineral King on October 2, 1969, but was no longer detectable on October 6. A search to reestablish contact was made on October 22, 1969, using the Department's airplane. On the first approach to the Sequoia National Park boundary from the west, along the East Fork of the Kaweah River, the doe was located in the area where she was destined to spend the winter; on a densely brushed west slope 2 miles south of Mild Ranch Peak, on the National Park boundary, and 9 miles west

of her summer area. Throughout the 1969–70 winter, weekly surveys were made with radio receivers. Signals were received on 21 different days of monitoring. This information indicated that the doe restricted her winter range to about ½ mile. Although intensive searches were made by up to four men crews a number of times and radio signals were received, often close by this animal, she was never sighted during her entire winter stay. The heavy density of brush and trees shielded her from observation. Presumably she lost her bell as none was heard during the searches. It is also presumed that this doe lost her fawn either in Mineral King or shortly after the winter migration as no sign of the fawn was noted during the winter.

On May 23, 1970, after 7 months on the winter range, radio contact was made with this doe, but on May 26, 1970, no signal was received, indicating she had started migration to the summer range. An immediate follow-up radio contact was made on the Mineral King summer range at the same location where she had been trapped the year before. This deer had returned from the winter range in less than 3 days and was one of the last to depart. This animal was at the original trapping site in September 1971 accompanied by a fawn. One of the two does equipped with an Electronics Unlimited collar was also seen within 100 yards of the original trap site in September 1971. This animal was accompanied by twin fawns.

Movements of Belled Deer

Deer movement between the Sequoia National Park and Mineral King during the summer was minor. Observation of belled deer indicated the does ranged over a very limited area, probably a ½-mile radius as noted for the doe with radio. The range for bucks was not established as the earmarked four were not seen after release. The majority of the Mineral King deer summer along the intermediate slope of the Mineral King basin (Figure 2).

The movement of deer to the winter range began October 5, 1969, when the first winter storm in the area dropped about 3 inches of snow on the Mineral King valley floor. The first recorded observation of belled deer movement was on October 7, 4 miles below Mineral King on Paradise Ridge by Art Norman of the Sequoia National Park. Field observations indicated that the bulk of the deer had moved out of Mineral King by October 16, 1969.

The main migration was generally along the higher elevations, and above the thick brush belt of the canyon, after leaving the general Atwell Mill area.

The first belled deer seen by Park personnel on the winter range was at Hospital Rock in the Sequoia and Kings Canyon National Park.

Sixty-five sightings were made of belled deer throughout the 1969–70 winter. We sighted the majority of the deer between Oak Grove and Red Hill on the south facing slope above the East Fork of the Kaweah River. Of these, an estimated 20 individual belled deer were seen, or 50% of those tagged at Mineral King. The most distant observation was made at Shepherds Cove later in the year, about 18 miles from the summer range and outside of what is considered the major concentration area of the Mineral King animals.

Migration dates show that 56% of the year, 205 days, was spent on the winter range and 44%, 160 days, on the summer range.

CONCLUSIONS AND MANAGEMENT CONSIDERATIONS

The Mineral King deer population should be held near 350 animals. This number appears to be satisfactory in relation to the habitat conditions, food supply, and present summer recreation use impact. Prior to 1959, range transects indicated that deer numbers exceeded the carrying capacity of this habitat. Presently deer numbers are much closer to what the range can safely support. Yearly buck harvests in the area should be continued under the present policy. If herd reduction becomes necessary, because of population increase, special hunts should be authorized.

The increase in public use after full development for recreation, and its impact on the deer habitat, and ultimately the deer population, is difficult to predict. Encroachment by the public on the key fawning areas could be a major problem. It may be necessary to restrict public use in these areas around the fringe of the valley floor, at critical times. However, experience shows that the bulk of the people will stay within the village area. Key areas must be mapped as protection units for wildlife.

If future hunting in Mineral King is curtailed or disallowed, the harvest and control of deer numbers will have to be accomplished on the Oak Grove area winter range by special hunts.

Improvements are needed to make Bureau of Land Management lands more accessible to hunters. Access to most of the Oak Grove winter range is extremely difficult due to the steep slopes, brush fields, and limited entry except along the Mineral King road. Closed access by private land owners to parcels of land on the winter range would limit the success of any deer harvest program, so acceptance by the owners to hunting in the area is desirable.

The deer winter range is in need of forage quality improvement, but this should not be undertaken until full harvest of deer equal to the annual production is obtained. Improvement of the winter range should go hand-in-hand with harvest and control of deer numbers. Otherwise, it would merely intensify the problems on the summer range.

ACKNOWLEDGMENTS

The authors appreciate and acknowledge the help provided by Mr. Richard Riegelhuth, Sequoia and Kings Canyon National Parks; Mr. Jack Young, Southern California Edison Company and other Edison employees; Mr. Bob Reser and others of the California Department of Fish and Game; and the Sequoia National Forest who participated in this endeavor.

REFERENCE

Dasmann, Raymond F. 1952. Methods for estimating deer population from kill data. Calif. Fish Game 38 (2): 225–233.

Calif. Fish and Game 58(2): 141–144. 1972.

RABIES IN A DEER[1]

D. T. CAPPUCCI, JR.
Veterinary Section, Calif. Dep. Public Health, 2151 Berkeley Way, Berkeley, 94704
and
W. M. LONGHURST
Department of Animal Physiology, University of Calif., Davis, 95616

Rabies was diagnosed in a Columbian black-tailed deer (*Odocoileus hemionus columbianus*). Two persons subsequently received postexposure antirabies treatment. The case documented herein represents California's fifth reported episode of rabies in deer.

INTRODUCTION

Members of the Cervidae appear to play a negligible role in the epidemiology of wildlife rabies, since they are largely unable to transmit infection (Karstad, 1962; Irvin, 1970). According to Chalmers and Scott (1969), rabies in deer might not be a dead-end infection since Cope and Duguid (1888) claimed to have demonstrated natural transmission among fallow deer (*Dama dama*) in Great Britain. Most instances of rabies in deer seem to be the result of attacks by rabid carnivores, and are considered incidental infections. On the other hand, the review by Irvin points out that in the roe deer (*Capreolus capreolus*) of central and western Europe the incidence of rabies has been reported to exceed 10%. In addition to the aforementioned species, isolated, sporadic cases of rabies have been reported in moose (*Alces alces*), reindeer or caribou (*Rangifer tarandus*), wapiti or American elk (*Cervus canadensis*), Virginia or white-tailed deer (*Odocoileus virginianus*), mule deer (*Odocoileus hemionus*), and red deer (*Cervus elaphus*)—(Cope & Duguid, 1888; Adami, 1889; Bernard, 1924; Calif. Dep. Public Health, 1938, 1939, and 1950; Wilson, 1949; Ballantyne and O'Donoghue, 1954; Schoening, 1956; Metelva and Rubanchik, 1959; Karstad, 1962; Center for Disease Control, U.S. Public Health Service, 1963–1970; Clausing, 1963; Kauker and Zettl, 1963; Pitzschke, 1963; Kaplan, 1966; Kauker, 1966; Muller, 1966; Schoop, 1966; Steck et al. 1968; Chalmers and Scott, 1969; Hole, 1969; Irvin, 1970). It should be clarified that some of the early reports of rabies in man and animals may be unreliable, since they were based solely on clinical observations or laboratory tests that were nonspecific for rabies.

Rabid deer are seldom recognized in California, although deer are the most abundant and most hunted big game animal in the state (Dasmann, 1968). Only four previous cases have been reported: one from Santa Clara County in 1938, two from Santa Clara County in 1939, and one from San Diego County in 1950 (Calif. Dep. Public Health, 1938, 1939, and 1950). During the aforementioned years, there existed a widespread cycle of epidemic/endemic canine rabies in California, including San Diego and Santa Clara counties. The domestic dog was the principal species involved and most likely the source of

[1] Accepted for publication January 1972.

infection for the deer; other species, including wildlife, were of minor importance during the cycle. The recent rabies infection documented herein represents the state's fifth reported case. It is California's first episode of rabies in deer to be laboratory confirmed by the fluorescent rabies antibody (FRA) and mouse inoculation tests; the four previous cases were diagnosed solely by microscopic examination for Negri bodies.

CASE REPORT

On August 30, 1971, a rancher from Yorkville, Mendocino County, discovered an adult, male Columbian black-tailed deer (*Odocoileus hemionus columbianus*) on his rural property. The animal displayed clinical signs of incoordination and hindquarter paralysis. It had moved only a few yards over 2 days observation. When approached by the rancher, the deer produced agonizing bellows of distress. The rancher subsequently sacrificed the animal and presented it to the University of California Hopland Field Station for laboratory examination.

A fresh carcass was received for necropsy. The deer was a 4-year-old buck with three points on each antler. The animal was in good condition, with ample fat reserves. A small, nearly-healed abrasion was observed on the external, ventral abdomen. The blood was thin, and the liver appeared pale and anemic. The lymph nodes seemed enlarged, and meningeal blood vessels were congested. Grossly, the following parasites were noted: eye worm (*Thelazia californiensis*), liver fluke (*Fasciola hepatica*), fleas (*Pulex simulans*), and flies (either *Neolipoptena ferrisi* or *Lipoptena depressa* or both)—(Walker and Becklund, 1970).

Tissue samples were taken to the University of California, School of Veterinary Medicine, at Davis, for histologic study. Negri bodies were not observed in brain tissue; lymph nodes and spleen were characterized by reactive hyperplasia of unknown cause. Specimens of brain tissue which were submitted to the Yolo County Health Department Laboratory yielded positive results for rabies by the FRA test. The diagnosis was also confirmed by repeat FRA tests, including specific staining inhibition control tests, and by isolation of rabies virus in suckling mice at the Viral and Rickettsial Disease Laboratory, Calif. Dep. Public Health (Lennette et al. 1965; Johnson, 1969).

Two individuals were exposed: one person lacerated his hand on bone tissue during gross examination of the carcass, while the other individual subsequently cut himself with a contaminated saw used in the necropsy. Both individuals received a 14-day course of duck embryo-origin rabies vaccine with boosters at 10 and 20 days after the completion of the initial series. Equine-origin antirabies hyperimmune serum was not administered. No adverse reaction to the immunizations was observed. Serum samples collected from the two individuals 3 weeks after completion of the immunization course were shown to have rabies virus neutralizing antibody titers of 1:16 and > 1:64, respectively, by fluorescent focus inhibition test in cell culture (Lennette and Emmons, 1971).

Rabies is known to be enzootic in many species of wild carnivores in California, including Mendocino County (Calif. Dep. Public Health, 1960–1971). Over the past several years, numerous gray foxes *(Urocyon cinereoargenteus)* and striped skunks (*Mephitis mephitis*) which showed clinical signs highly suggestive of rabies have been observed on the ranch, but none were submitted for laboratory examination. Coincidentally, a gray fox, which acted quite aggressive, was shot and killed on the same rural premises a few days after discovery of the rabid deer. Tissues from the fox were unavailable for analysis.

This episode emphasizes the importance of considering rabies in the differential diagnosis of encephalitis or illness with abnormal behavior in deer, and the need for particular caution and good aseptic technic in performing necropsies on such animals. Persons who are at risk of exposure to rabid animals, either from bites or from necropsy procedures on brain tissue should have preexposure immunization against rabies, with serologically proven antibody response to the vaccine.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of Drs. J. C. DeMartini, R. W. Emmons, G. L. Humphrey, and J. H. Oh; Messrs. O. Brunetti, A. B. Hulbert, D. Stork, and J. D. Woodie; the Mendocino and Yolo County Health Departments; and the Viral and Rickettsial Disease Laboratory of the Calif. Dep. of Public Health.

REFERENCES

Adami, M. 1889. An epidemic of rabies in a herd of deer. Ann. Inst. Pasteur. 3(11):658–663.

Ballantyne, E. E. and J. G. O'Donoghue, 1954. Rabies control in Alberta. J. Amer. Vet. Med. Assn. 125(931):316–326.

Bernard, A. 1924. A rabid deer. Allatorv. Lap. (ung.) NR 23/24. Ref.: Munch. tierarztl. 77(19): 238, 1926.

California Department of Public Health. 1938, 1939, 1950, 1960–1971. Epidemiologic and laboratory reports of animal rabies. C.D.P.H., Berkeley, Calif.

Center for Disease Control, U.S. Public Health Service. 1963–1970. CDC zoonoses surveillance-annual rabies summaries, C.D.C., Atlanta, Ga.

Chalmers, A. W. and G. R. Scott. 1969. Ecology of rabies. Trop. Anim. Hlth. Prod. 1:33–55.

Clausing, D. 1963. Problems of rabies control. Mh. Vet. Med. 18:29–33.

Cope, A. C. and W. Duguid. 1888. Report on the diseases which have existed among animals in Great Britain and among animals in foreign countries in 1887. Ann. Rep. Agric. Dept. Privy. Council Off. on the Contagious Diseases, Inspection, and Transit of Animals Act 1887. H.M.S.O., London, p. 12–73.

Dasmann, W. P. 1968. Big game of California, Calif. Dep. Fish and Game, Sacramento, Calif. p. 5–14, 45–47.

Hole, N. H. 1969. Rabies in quarantine. Nature, Lond. 224(5216):244–246.

Irvin, A. D. 1970. The epidemiology of wildlife rabies. Vet. Rec. 87(12):333–348.

Johnson, H. N. 1969. Rabies virus. In: Diagnostic procedures for viral and rickettsial infections. 4th ed. Edited by E. H. Lennette and N. J. Schmidt. Amer. Public Hlth. Assn., New York, N.Y. p. 321–353.

Kaplan, M. 1966. World survey of rabies. In: Int. Symp. Rabies, Talloires, 1965. Symp. Ser. Immunobiol. Standard. Karger, Basel. 1:215–229.

Karstad, L. 1962. Viral and rickettsial diseases of deer: a review. In: Proc. 1st Natl. White-tailed Deer Disease Symp., Univ. of Georgia, Athens, Ga. p. 138–144.

Kauker, E. 1966. Rabies in central Europe from 1953 to 1966. Rep. Heidelberg Acad. Sci., Handbook No. 4. p. 5–30.

Kauker, E. and K. Zettl. 1963. The epidemiology of sylvan rabies in central Europe and the possibilities of combating it. Vet. Med. Nach. No. 2/3:96–116.

Lennette, E. H. and R. W. Emmons. 1971. The laboratory diagnosis of rabies: review and prospective. *In*: Rabies. Proc. of Working Conference on Rabies Sponsored by the Japan-United States Cooperative Medical Science Program, Tokyo, Japan. Edited by Y. Nagano and F. M. Davenport. Univ. of Tokyo Press, Tokyo. p. 77–94.

Lennette, E. H., J. D. Woodie, K. Nakamura, and K. L. Magoffin. 1965. The diagnosis of rabies by fluorescent antibody method (FRA) employing immune hamster serum. Health Lab. Sci. 2:24–34.

Metelva, P. I. and I. S. Rubanchik. 1959. Rabies in reindeer in the Arctic. Veterinariya, Moscow. 36(1):47–48.

Muller, J. 1966. The reappearance of rabies in Denmark. In: Int. Symp. Rabies, Talloires, 1965. Symp. Ser. Immunobiol. Standard. Karger, Basel. 1:239–244.

Pitzschke, H. 1963. Rabies in roe deer-epidemiological and food hygiene aspects. Mh. Vet. Med. 18:151–154.

Schoening, H. W. 1956. In: Animal Diseases, Yearbook of Agriculture. U.S.D.A., Washington, D.C. p. 195–202.

Schoop, G. 1966. Epidemiology of rabies in the western part of Germany. In: Int. Symp. Rabies, Talloires, 1965. Symp. Ser. Immunobiol Standard. Karger, Basel. 1:237–238.

Steck, F., P. Addy, E. Schipper, and A. Wandeler. 1968. The current course of the rabies epidemic in Switzerland. Schweiz. Arch. Tierhlk. 110(12):597–616.

Walker, M.L. and W. W. Becklund. 1970. Checklist of the internal and external parasites of deer. *Odocoileus hemionus* and *O. virginianus*, in the United States and Canada. Index-Catalogue of Medical and Veterinary Zoology. Special Publication No. 1. U.S.D.A., Washington, D.C. p. 3, 15, 21, 24–26.

Wilson, J. E. 1949. Occurrence of rabies in deer *(Odocoileus virginianus)*. J. Mammal. 30(2):203.

NOTES

NONREPORTING OF TAGGED LARGEMOUTH BASS, 1966–1969

During a tagging investigation of mortality rates of largemouth bass, *Micropterus salmoides*, varying proportions of legend-bearing nonreward, $5-reward, and $1-reward tags were used annually from 1966 through 1969 at Merle Collins Reservoir, Yuba County, California (Table 1). The tags used were disk dangler (modified Atkins) (Chadwick 1963). The objectives were to measure the proportion of angler nonresponse between reward and nonreward tags and between $5 and $1 reward tags. The former estimate was used to correct exploitation rates for the first year of the study when no reward tags were used. In addition, this value would provide correction factors in future tagging studies of largemouth bass in similar waters where estimation of exploitation rate was the principal goal. The latter would provide insight into the magnitude of the reward necessary to induce anglers to return tags. Definitions, assumptions, and estimation of nonresponse follow Chadwick (1968) and Rawstron (1971).

Anglers returning tags received the appropriate reward, a commendation card, and a letter explaining the goals of the study. Although a creel census was conducted all year on each weekend and two rotating weekdays each week, no tags were supposed to be collected by the census clerk. The data presented here generally represent mail returns only. Data include all tags returned through April 1971.

Nonreporting of tags ranged from 0.54 in 1966 to 0.15 in 1967 (Table 1). The weighted mean value for the whole study amounted to 0.34. The most useful estimates came from 1968 and 1969 after the lake had been opened for several years to fishing. These values, 0.34 and 0.39, respectively, were similar to the estimate of 0.38 reported for largemouth bass at Folsom Lake, California (Rawstron 1971). The low value in 1967 resulted from a creel census clerk who, against instructions, collected some nonreward tags from anglers who had previously caught other fish tagged with nonreward tags and did not wish to receive another commendation card. Those, unfortunately, can not be identified in the 1967 mail returns. In addition, three times as many reward tagged as nonreward tagged fish were liberated in 1967, and some anglers thought all tags returned brought a reward. The higher value in 1966 probably resulted from unawareness of anglers of the presence of reward tags. This is particularly true of repeat anglers who had fished the lake in 1965 when no rewards were offered.

Contrary to the results of a study at Folsom Lake (Rawstron 1967), anglers returned a higher total proportion (0.79) of reward tags from smaller bass than for larger bass (0.69). A similar difference in reponse also existed between these same length classes of nonreward tags, 0.51 and 0.42, indicating a possible lower vulnerability of larger bass. This also contradicts the results from Folsom Lake where all bass were deemed equally vulnerable. Nonresponse from the two groups (0.35, $<$ 11.0 inches; 0.38, $>$ 11.0 inches), however, did not differ as greatly

TABLE 1. **Number of Largemouth Bass Tagged and Returned * by Length Class, 1966–1969—Merle Collins Reservoir**

Fork length (inches)	1966			1967			1968		1969	
	Nonreward	$5 reward	$1 reward	Nonreward	$5 reward	$1 reward	Nonreward	$5 reward	Nonreward	$5 reward
8.0–10.9	9 (4)	4 (3)	5 (3)	19 (11)	38 (30)	11 (7)	375 (201)	97 (78)	162 (74)	154 (115)
11.0+	23 (4)	13 (7)	12 (7)	6 (4)	47 (30)	2 (2)	25 (10)	3 (2)	38 (21)	46 (37)
Total	32 (8)	17 (10)	17 (10)	25 (15)	85 (60)	13 (9)	400 (211)	100 (80)	200 (95)	200 (152)
Nonresponse	0.54	----	0.00	0.15	----	0.02	0.34	----	0.39	----

* Number returned in parentheses.

as was indicated by Folsom Lake anglers whose nonresponse for smaller bass was 0.54 and 0.24 for larger fish (Rawstron 1971).

No real differences between reporting of $1 and $5 tags were noted (Table 1). In 1966 when 17 of each were used, anglers returned 10 of each value. In 1967 nonreporting of the $1 tag amounted to only 0.02. Sample size was small, but these data indicated that $1 was probably sufficient inducement to return tags at this lake.

This work was performed as part of Dingell-Johnson Project F-18-R, "Experimental Reservoir Management", supported by Federal Aid to Fish Restoration Funds.

REFERENCES

Chadwick, Harold K. 1963. An evaluation of five tag types used in a striped bass mortality rate and migration study. Calif. Fish Game 49(2):61–83.

———. 1968. Mortality rates in the California striped bass population. Calif. Fish Game 54(4):228–246.

Rawstron, Robert R. 1967. Harvest, mortality and movement of selected warmwater fishes in Folsom Lake, Calif. Calif. Fish Game 53(1):40–48.

———. 1971. Nonreporting of tagged white catfish, largemouth bass, and bluegills by anglers at Folsom Lake, California. Calif. Fish Game 57(4):246–256.

Robert R. Rawstron, Inland Fisheries Branch, California Department of Fish and Game, Sacramento, California. *Accepted December 1971.*

TAILLESS DOVER SOLE FROM OFF THE OREGON COAST

During the period March 1966 to February 1968, six tailless Dover sole (*Microstomus pacificus*) were noted (Figure 1). Two of the fish were caught near the mouth of the Columbia River and four others off the southern Oregon coast. The small specimens were captured with small mesh otter trawls during juvenile groundfish and shrimp survey cruises. The large specimen was caught by a commercial trawl vessel.

Such occurrences are rare. During research cruises in 1966–68 when the five small specimens were found, 10,400 Dover sole were examined. In routine sampling of commercial landings between 1948 and 1969, examination of nearly 100,000 Dover sole produced only one commercial-sized tailless individual. Such a handicap must result in low survival.

Townsend (1936) lists the vertebral range of Dover sole as 51–54 with a mode of 51 (mean 51.8). Vertebral counts of the six fish range from 40–48 (Figure 1). Counts were determined by dissection. The hypural plate is missing from all fish and the dorsal and anal fins have joined. It was not possible to determine whether the tailless condition is due to injury or mutation.

Thanks are due to Michael J. Hosie, fish sampler, who recovered and preserved the large specimen.

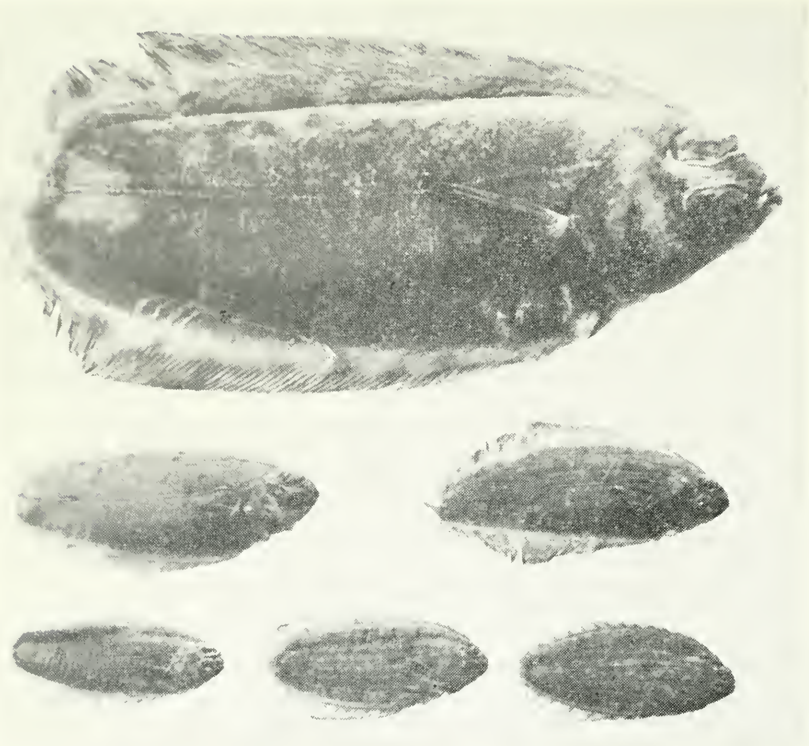

FIGURE 1. Dover sole from Oregon coast. Specimens are numbered from top to bottom and left to right.

Specimen number	Date of capture	Depth (fms)	Locality		Age	Length (mm)	Vertebral count
			Latitude	Longitude			
1	7-10-67	50	43°48′ N	124°18′ W	5	199	40
2	8- 3-67	41	46°06′ N	124°10′ W	1	78	45
3	7-18-66	34	46°30′ N	124°17′ W	1	76	44
4	3-26-67	51	42°56′ N	124°40′ W	1	53	47
5	3-27-67	52	42°35′ N	124°35′ W	1	53	48
6	3-26-67	51	42°58′ N	124°38′ W	1	54	43

LITERATURE CITED

Townsend, L. D. 1936. Variations in the meristic characters of flounders from the northeastern Pacific. Rept. Inter. Fish Comm., No. 11, 24 pp.

Robert L. Demory, Fish Commission of Oregon, Newport, Oregon 97365. *Accepted December, 1971.*

A POLYPROPYLENE LIGHT TRAP FOR AQUATIC INVERTEBRATES

Researchers investigating waterfowl botulism outbreaks, have suspected that aquatic invertebrates might be sources of toxin produced by the bacterium *Clostridium botulinum*, type C (Hunter, et al. 1970; Enright, 1971). To study their role in botulism outbreaks, we needed a method to collect large masses of invertebrates for bioassay while, at the same time, monitoring their population dynamics.

Tow-net and dredge techniques proved unsatisfactory in shallow marsh ponds because undesirable mud, plants, sticks, and other debris as well as invertebrates were gathered. Collections from tow nets were bulky to package, hard to keep fresh, and required tedious, time-consuming separation of invertebrates from detritus. Washino and Hokama (1968) encountered similar problems when they sampled rice fields as part of their mosquito control research. They used an aquatic light trap after unsuccessful attempts to adapt other limnological collecting apparatuses for sampling shallow waters. Their traps were constructed from 1 quart glass jars (Washino, pers. comm.). However, we found glass traps to be unsatisfactory because they were fragile and difficult to fabricate which made production uneconomical.

Initial cost eliminated plexiglass as an alternate material, although it may have proven satisfactory in other ways. Plastic mayonnaise jars used in wholesale foods packaging were inexpensive but were not available when needed. Consequently, we purchased 1-gallon polypropylene jars from a scientific products company.

Construction was simple: the bottom was cut from a jar with an electric table saw. A 7-inch inverted polypropylene funnel was fitted in its place and bonded to the jar by heat fusion. A light unit from a highway-barrier flasher was flattened and cut so that it could be screwed into the threads of the jar lid. This eliminated bonding the unit to the lid and permitted easy replacement if necessary. The socket and bulb were protected against moisture by encasing them within a drilled stopper. Wires and socket base were sealed with a rubber-silicone compound. Wires for the light were passed through a hole drilled in the lid, to a 6-volt lantern battery (Figure 1). Heavy duty batteries with metal cases and thumb screw terminals are weatherproof and give long trouble-free service.

In the marsh, the trap was partially submerged to a marked waterline and suspended by a harness made of stout cord. The harness was suspended from a crosspiece clamped ("C" clamp) to a 2″ x 2″ x 6′ stake firmly set in the pond bottom. A large circumference hose clamp (No. 72) held the battery to the stake. Clamps permitted battery and trap to be easily adjusted to any water level (Figure 2). A rubber band around both trap and stake offset the tendency of the polypropylene to float and kept the trap upright against wind and wave action.

For laboratory analysis we needed quantities of fresh invertebrates. To this end we omitted any killing agents and strained the contents of each trap through fine mesh netting to eliminate excess water. Invertebrates were placed in 1 quart polypropylene containers which were promptly iced. Such collections would remain fresh and contain live organisms when opened in the laboratory several days later.

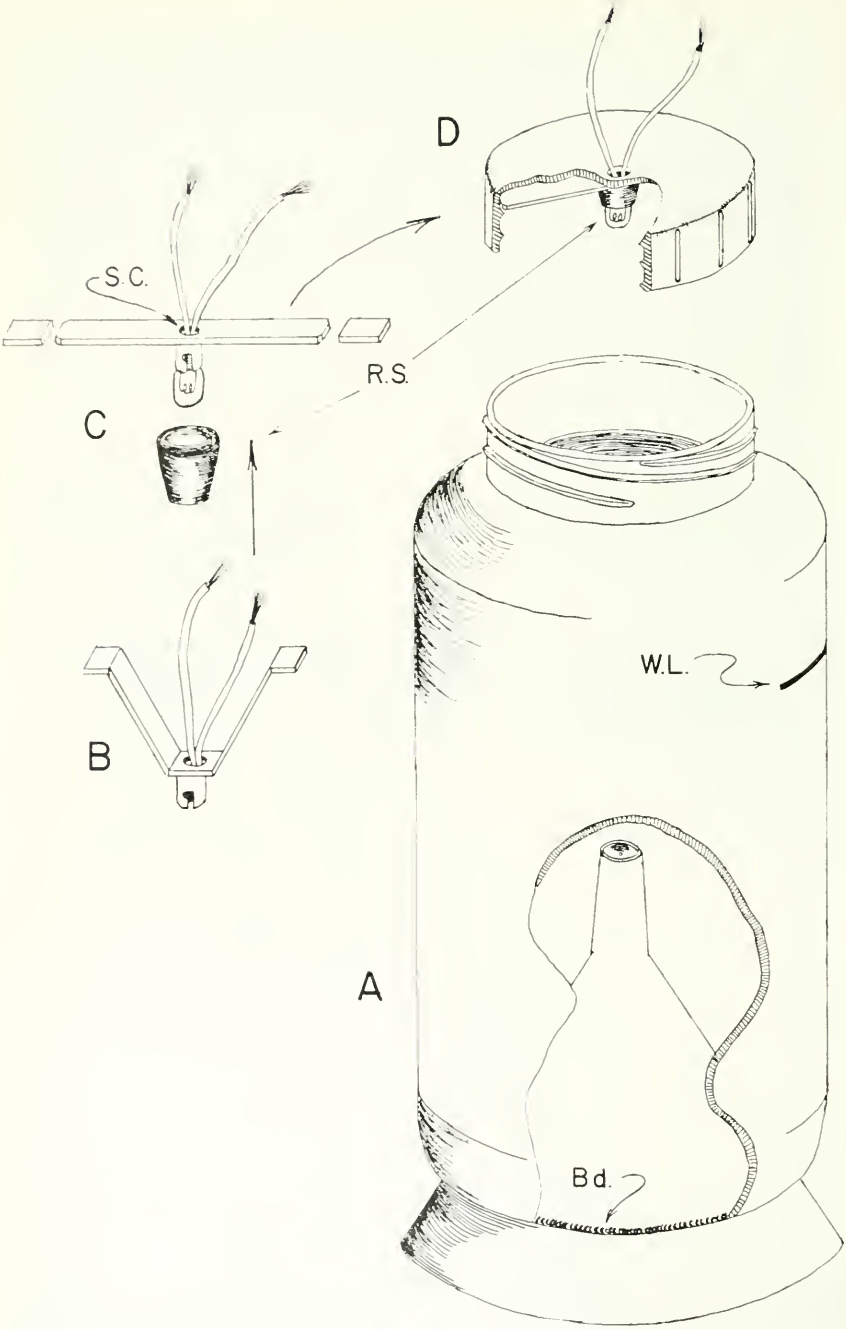

FIGURE 1. Plan for aquatic light trap showing construction details. A—Polypropylene jar with inverted polypropylene funnel in place. WL—Marked waterline. Bd.—Heat fusion bond. B—Highway barrier flasher as manufactured. C—flasher unit flattened, cut and wires sealed. S.C.—Placement of silicone rubber compound. R.S.—Drilled rubber stopper (= 1). D—Placement of unit in lid. Drawing by L. Espinosa.

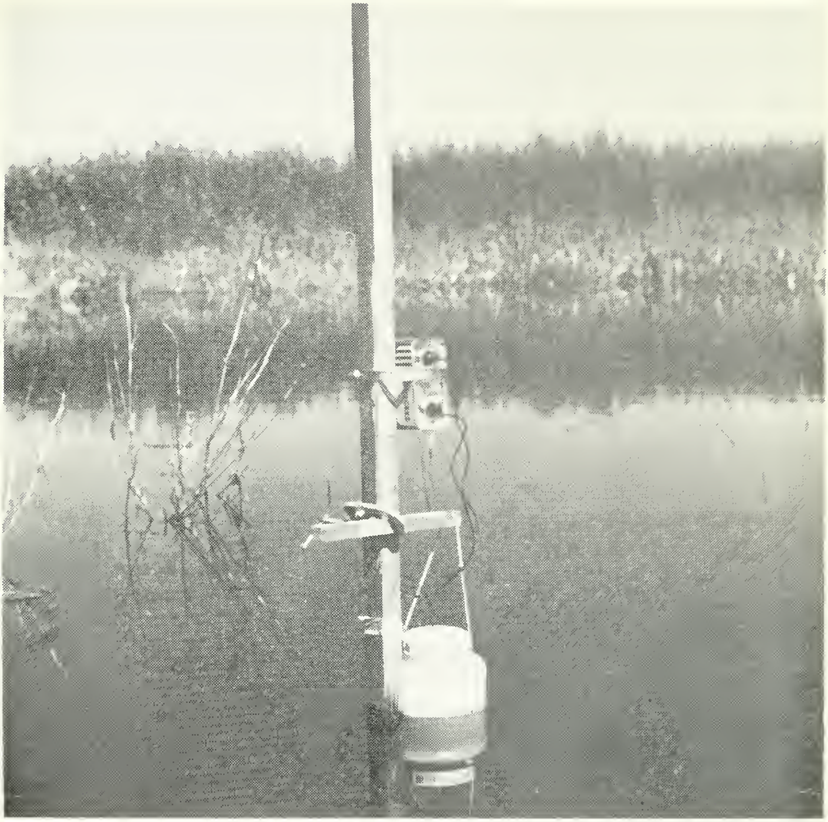

FIGURE 2. Light trap set in marsh. Photo by L. Espinosa.

Collections consisted almost entirely of invertebrates which were easily sorted into bioassay samples. Using this trap we have caught immature and adult insects of the orders Hemiptera (Corixidae, Notonectidae, Belostomatidae), Coleoptera (Haliplidae—adults only, Hydrophilidae, Dytiscidae), Odonata (immature only), Ephemeroptera (immature only) and all stages of the crustacean orders Cladocera, Amphipoda, Ostracoda, and Copepoda.

Although light shining through polypropylene is not as bright as it would be through glass, our device is adequately efficient. For instance, using 12 traps simultaneously, we collected well over a kilogram of invertebrates at times; more than 250 g per trap in some cases. Often the traps gathered invertebrates that had not been detected by other means and which were in quantities large enough for bioassay.

It is significant that despite lower illumination levels polypropylene can be used to make a workable light trap. Other than reduced light transmission there are no apparent drawbacks to this trap that are not flaws of similar glass devices.

REFERENCES

Enright, Christine A. 1971. A review of research on Type C botulism among water birds. Colorado Cooperative Wildlife Research Unit. Colorado State Univ. Fort Collins. 22 p.

Hunter, Brian F., William E. Clark, Patricia J. Perkins and Phillip R. Coleman. 1970. Applied botulism research including management recommendations—A progress report. Calif. Dep. Fish and Game, Sacramento. 87 p.

Washino, R. K., and Y. Hokama. 1968. Quantitative sampling of aquatic insects in a shallow-water habitat. Ann. Ent. Soc. Amer. 61(3): 785–786.

Lawrence R. Espinosa and William E. Clark, California Department of Fish and Game, Wildlife Management Branch. *Accepted December 1971. This study was supported by a grant from the U.S. Bureau of Sport Fisheries and Wildlife and by Federal Aid to Wildlife Restoration Project W-52-R "Wildlife Investigations Laboratory."*

TOLERANCE OF HIGH SALINITY BY THE PILEWORM, *NEANTHES SUCCINEA*, FROM THE SALTON SEA, CALIFORNIA

The pileworm is an important item in the food chain leading to the orangemouth corvina (*Cynoscion xanthulus*) in the Salton Sea (Walker 1961). A fishery of an estimated 359,000 angler trips annually, with a harvest of 346,000 fish, is supported by this species (Robert G. Hulquist, Calif. Dep. of Fish and Game, pers. comm.). Increasing salinity is threatening the existence of this fishery. Walker (1961) predicted that it will be destroyed by 1980 if remedial actions are not taken to control salinities at a safe level. In 1966, the California Department of Fish and Game began a study to determine the tolerances to high salinities by the various organisms in the food chain as a basis for recommending target levels for a control plan (Hanson 1970). The salinity tolerance of adult pileworms was tested in laboratory experiments during January and February 1968.

Pileworms for the test were obtained by screening bottom samples taken along the shoreline. Test specimens were held in the laboratory for 3 to 5 days in shallow trays containing a mixture of bottom mud and clean sand covered with about an inch of water. Tests were conducted in 1-gallon glass jars containing the mud and sand mixture and 1 inch of Salton Sea water at various test concentrations. These concentrations were obtained by slow evaporation of the water. Ten worms were placed in each jar with no acclimation to hypersalinity. Controls (37‰) were run concurrently and all tests were performed in duplicate or triplicate. Exposure time was 96 hr.

Pileworms tolerated extremely high salinities (Table 1). Survival was 93.3% at 67.5‰. The lowest survival was 68.0% at 62.5‰. However, it appears that in this instance mortality was due to causes other than salinity, since mortalities occurred in all concentrations, including the controls.

Whether the pileworm can tolerate salinities higher than 67.5‰ was not determined, although it appears that they could. The fishery is expected to collapse, however, long before salinities become this high.

TABLE 1. **Percentage Survival of *Neanthes succinea* After Exposure to High Salinities for 96 Hr**

Test number	Controls		42.5 ‰		45 ‰		50 ‰		55 ‰		60 ‰		62.5 ‰		65 ‰		67.5 ‰	
	Number tested	Percent survival	Number tested	Percent survival	Number tested	Percent survival	Number tested	Percent survival	Number tested	Percent survival	Number tested	Percent survival	Number tested	Percent survival	Number tested	Percent survival	Number tested	Percent survival
1	20	100	20	95.0	--	--	--	--	--	--	--	--	20	75.0	--	--	--	--
2	30	96.7		--	30	90.0	--	--	30	93.3	--	--	30	63.3	--	--	--	--
3	30	86.7	--	--	--	--	30	96.7	30	86.7	--	--	--	--	30	93.3	--	--
4	30	96.7	--		--	--	--	--	30	90.0	30	100	--	--	--	--	30	93.3
Totals	110	91.6	20	95.0	30	90.0	30	96.7	90	90.0	30	100	50	68.0	30	93.3	30	93.3

Moreover, reproduction of the pileworm would probably be adversely affected at lower salinities.

This work was performed as part of Dingell-Johnson Project F-24-R, "Salton Sea Investigation", supported by Federal Aid to Fish Restoration funds.

REFERENCES

Hanson, Jack A. 1970. Salinity tolerances for Salton Sea fishes. Calif. Dep. Fish and Game, Inland Fish. Admin. Rep. No. 70–2, 8 p.

Walker, Boyd W. (editor) 1961. The ecology of the Salton Sea, California, in relation to the sportfishery. Calif. Dep. Fish and Game, Fish Bull. (113) : 1–204.

Jack A. Hanson, Inland Fisheries Branch, California Department of Fish and Game. *Accepted October 1971.*

RANGE EXTENSION OF *PALAEMONETES PALUDOSUS* (GIBBES) IN CALIFORNIA

The freshwater decapod shrimp, *Palaemonetes paludosus*, was introduced into the lower Colorado River in 1958 by the California Department of Fish and Game (Hayden and Ringo 1963) and was raised commercially prior to 1967 at Sargent's Tropical Fish Farm, located on the southeast side of the Salton Sea below the Hot Mineral Spa. The shrimp has not become numerous in the section of the Colorado River where it was introduced, but it is abundant in the Rio Hardy and Colorado rivers, Baja California (St. Amant and Hulquist 1969). The shrimp has recently appeared in waters below Sargent's Fish Farm.

On October 20, 1970, and March 16, 1971, John Day collected shrimp in a drainage ditch northeast of the Salton Sea, Imperial County. The ditch originates in the Hot Mineral Spa, a series of warm springs, and flows into the Salton Sea. The senior author collected 20 adult and juvenile shrimp in the ditch on March 23, 1971. The location of these collections is northeast (upstream) of Highway 111 where the ditch flows over the Liquid Waste Disposal Road. On April 8, 1971, St. Amant and Richard Smith collected additional shrimp in this area. Shrimp were also collected immediately below Highway 111. No shrimp were found between here and the Salton Sea.

An inspection on April 15, 1971, of the water areas in the Hot Mineral Spa vicinity by the senior author and Kurt and Bret St. Amant revealed shrimp in an isolated sump pond at the Sargent's Tropical Fish Farm. This fish farm has been closed since 1967. Two hundred shrimp were collected and numerous sailfin mollies, *Poecilia latipinna*, were also observed in this pond. In 1965 the pond contained a large resident population of *Tilapia mossambica* (St. Amant 1966), but no shrimp were observed at that time. Three shrimp were also found in the concrete box that once received hot water from the Spa. St. Amant collected additional shrimp in the ditch below Highway 111 with minnow traps on April 25, 1971.

The senior author identified the shrimp to be *P. paludosus*. Confirmation of identification was made by U. Chivers, California Academy of Sciences, and Joel W. Hedgpeth, Oregon State University.

In all of the collections the shrimp were associated with aquatic vegetation, *Chara* sp. and filamentous algae.

We believe the population present in the Hot Mineral Spa area and the drainage ditch is the result of escapement and subsequent reproduction of shrimp from Sargent's Tropical Fish Farm.

The shrimp could easily enter the Salton Sea and become established; however, it is doubtful they will become abundant. All *P. paludosus* collected in California have been closely associated with aquatic vegetation (Hayden and Ringo 1963, St. Amant and Hulquist 1969). The Salton Sea is nearly devoid of aquatic plants.

REFERENCES

Hayden, Robert P. and Robert D. Ringo. 1963. Introduction of *Palaemonetes paludosus*, a freshwater shrimp, into the lower Colorado River. Calif. Fish Game 49(4): 304–306.

St. Amant, James A. 1966. Addition of *Tilapia mossambica* Peters to the California Fauna. Calif. Fish Game 52(1): 54–55.

St. Amant, James A. and Robert G. Hulquist. 1969. *Palaemonetes paludosus* collected in the Rio Hardy and Colorado River, Baja California. Calif. Fish Game 55(3): 252.

James A. St. Amant and John S. Day, Inland Fisheries, Region 5, California Department of Fish and Game. *Accepted November 1971.*

BOOK REVIEWS

The Ecology of Running Waters

By H. B. N. Hynes; Univ. of Toronto Press, Buffalo, N. Y., 1970; xxiv+ 555 p. $25.

At last a text is available on stream limnology. *The Ecology of Running Waters* provides a comprehensive and critical review of the literature on the biology of rivers and streams. Over 1,500 references are cited, including many very informative foreign studies. Unfortunately, the book does not include literature published after 1966 and this is attributed to the fact it took the publishers 2 years to move the book from final galley proofs to printing. Nevertheless, the book is very informative and is a significant contribution to the literature on stream ecology.

Almost half the book deals with lotic invertebrates, a bias admitted by the author. However, most studies within the last 40 years have been on invertebrates, so the book actually reflects the subject area where most studies have been carried out. The first three chapters deal with water flow in stream channels, and the physical and chemical characteristics of flowing water. The next three chapters are devoted to attached algae, higher plants and plankton. Eight chapters summarize the composition of the benthic invertebrate fauna, anatomical and behavioral adaptations of benthic invertebrates, feeding mechanisms and food of benthic invertebrates, factors controlling benthic invertebrates, quantitative study of benthic invertebrates, effects of down-stream movements of organisms on the benthos, and life histories and seasonal cycles of benthic invertebrates. Fishes of running water are treated only lightly, perhaps because of the immense volume of literature available to fish ecologists. The four chapters devoted to fish are quite comprehensive, however. They describe the species of fishes found in running water, ecological factors affecting fishes, movement and breeding of fishes, and the feeding habits of fishes. Dr. Hynes makes a plea to fishery biologists and fish ecologists to "separate ecology from fishery biology, and for ecologists to forget that fishes can be eaten and angled for and start to find out more about them as animals". Fishery biologists tend to find out what happens but not why or how it happens. This is a plea for a more general approach to fish ecology. One short chapter is devoted to vertebrates other than fishes which inhabit running waters. The remaining four chapters deal with longitudinal zonation, special habitats, stream ecosystems and the effects of man on water courses.

The tables and figures are of high quality, not excessive, and add useful support to the text. There are separate subject and organism indices which make both quite useful. I found only a few errors in the book and this was phenomenal in light of the great subject matter contained in the text. None of these errors was significant; therefore, I will not list them. Instead, I'm pointing to the fact that much has been written on stream ecology in the past 5 years and that the absence of these references prematurely ages the book. Had *The Ecology of Running Waters* been published in 1968 rather than in 1970, it would have received much more praise. Dr. Hynes has provided, however, a badly needed foundation for stream ecology and his thorough treatment of the subject makes this book a "classic" which should be included in every stream limnologist's library.—*James W. Burns.*

Systematics, Variation, Distribution, and Biology of Rockfishes of the Subgenus Sebastomus (Pisces, Scorpaenidae, Sebastes)

By Lo-chai Chen; Bulletin of the Scripps Institutian of Oceanography, University of California, La Jolla, California. University of California Press, Vol. 18, 1971; VI—115 p; $6.00 paper.

Dr. Chen has made an important contribution to what may be referred to as "phase three" in the taxonomy and biology of Eastern Pacific scorpaenids. "Phase one" was the sorting-out of genera and species by pioneer ichthyologists such as Ayres, Girard, Jordan, Gilbert, and the Eigenmanns. From about 1850 to 1900 these original workers described most of the *Sebastes* now recognized along the Pacific coast. Since 1900 only a few taxonomic adjustments were made in this group until J. B. Phillips's work appeared in 1957. Phillips embarked upon "phase two": the amassing of detailed morphometric, meristic, and color data on each of the recognized California rockfishes. The result was Fish Bulletin 104, the treatise used by all those working on Pacific coast rockfishes.

Subsequent to Phillips's work there has been a spurt of interest in scorpaenid taxonomic and biological studies. Since 1964 there have been seven new species of

Sebastes described frequenting California waters, and two others have been removed from synonomy. Four of the new species appear in Chen's work (*ensifer*, *rosenblatti*, *simulator*, and *lentiginosus*); John Fitch described *phillipsi* in 1964; Westrheim and Tsuyuki described *reedi* in 1967; and Tsuyuki and Westrheim named *caenaematicus* in 1970. At the present time there is still another California rockfish being described by Bob Lea and John Fitch. The two that were removed from synonomy were *babcocki* and *rufus*. Present-day taxonomists have at their disposal Phillips's work plus electropherograms and sophisticated statistical methods; therefore further clarification, discovery, and classification are inevitable.

Chen's publication gives a complete formal presentation of all the species in the subgenus *Sebastomus*, encompassing 13 species, 10 of which occur in California waters, and six of which are described as new species in this work. One of these, *S. ensifer*, is a new name for the invalid *S. rhodochloris*. The taxonomic treatment and synonomy of each species are complete, however electrophoretic analysis was apparently not conducted in this study. Included are a dichotomus key to identify the species of the subgenus *Sebastomus* and a glossy black-and-white print of each taxon. Even though there is no doubt in either Chen's or the reviewer's mind that the new species described are valid, the reviewer has encountered a few specimens of this group that defy positive identification. The separation of *S. simulator* and *S. helvomaculatus* is extremely delicate, and when identifying deep-water specimens of *S. chlorostictus*, *S. rosenblatti*, and *S. eos*, the differences are not always as distinct as indicated by the wording of the key. This is understandable for as Chen states (page 40) members of the genus are "very similar" and "Species separation generally involves minor differences in body configuration, coloration, and meristic and morphometric combinations."

One of the more valuable contributions of the publication is Chen's discussion and generalized comments on speciation, variation, geographic distribution, and biology of many of the other species of eastern Pacific *Sebastes*. Hiding behind the formal, erudite title, which indicates only a specific detailed taxonomic study of a relatively small group of fish, lie important data for fishery scientists involved in age, growth, and morphometric studies. Chen's statistical discussion of his interpretation of Lee's phenomenon, his graphic demonstration of allometric growth patterns of various body structures, and his indications of age-related mortality are important contributions to all fishery science. There is also a table listing the geographic limits of all eastern Pacific *Sebastes* including range extensions for 34 species. Because the cost may be high for students to own a copy of their own, academic libraries and instructors are encouraged to obtain "school copies." Even though it is over-priced, those of us working in the field of fisheries should obtain our own copy.—*Dan Miller*

If Deer Are To Survive

By William Dasmann; A Wildlife Management Institute book, published by Stackpole Books, Comeron and Kelker Streets, Harrisburg, Pa. 17105, 1971; 128 p. illustrated. $4.95.

With his vast forest and wildlife experience, the author points out the need for greater cooperation between sportsmen, wildlife and forest managers to make multiple land management a reality, rather than a theoretical management concept.

Some eleven chapters or eighty pages are devoted to evaluation of deer, their range and biological requirements, the characteristics of deer forage, herbaceous, browse and mast or fruit crops, and supplemental feeding. Livestock-deer forage relationship and competition is briefly discussed as is the deer-predator relationship. Although most of the text is directed towards the biological requirements of deer, the author stresses that regulation of hunting seasons is no longer an adequate means of sustaining deer herds. He states a need for a more imaginative habitat management program and uses a title implying a large treatise on management; however, only three chapters comprising 27 pages are devoted to this important subject.

The reference list includes 184 authors and subjects. An information kit comprised of important food plants of deer across the nation and a list of the crude protein levels for some western and southern range plants is also included.—*G. C. Ashcraft.*

printed in CALIFORNIA OFFICE OF STATE PRINTING
82862—800 1-72 5,300

Notice is hereby given that the Fish and Game Commission shall meet on April 7, 1972, at 9:00 AM in the auditorium of the Resources Building, 1416 Ninth Street, Sacramento, California, to receive recommendations from its own officers and employees, from the Department of Fish and Game and other public agencies, from organizations of private citizens, and from any interested person as to what, if any, orders should be made relating to birds or mammals, or any species or variety thereof for the 1972 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet at 9:00 AM on April 28, 1972, in Room B-109, State Building, 1350 Front Street, San Diego, California, for public discussion of and presentation of objections to, the proposals presented to the Commission on April 7, 1972, and after consideration of such discussion and objections the Commission shall publicly announce the regulations it proposes to make relating to birds or mammals, or any species or variety thereof, for the 1972 hunting season.

Notice is hereby given that the Fish and Game Commission shall meet on May 26, 1972, at 9:00 AM in Room 1138, of the New State Building, 107 South Broadway, Los Angeles, California, to hear and consider any objections to its determinations or proposed orders in relation to birds and mammals for the 1972 hunting season, such determinations resulting from hearing held on April 28, 1972. This notice is published in accordance with the provisions of Section 206 of the Fish and Game Code.

FISH AND GAME COMMISSION
Leslie F. Edgerton
Executive Secretary

POSTMASTER: RETURN POSTAGE GUARANTEED
Editor, CALIFORNIA FISH AND GAME
CALIFORNIA DEPARTMENT OF FISH AND GAME
987 JEDSMITH DRIVE, SACRAMENTO, CALIF. 95819